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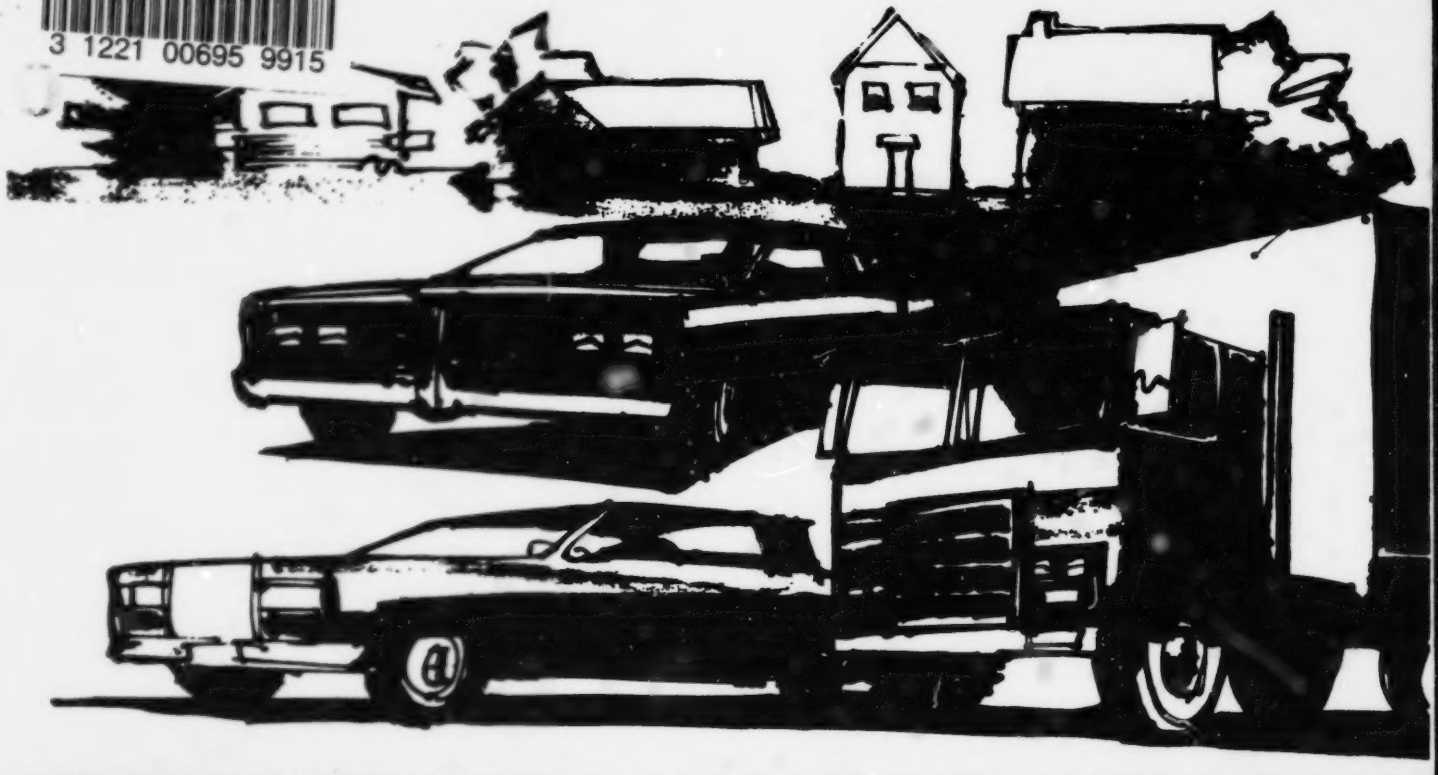
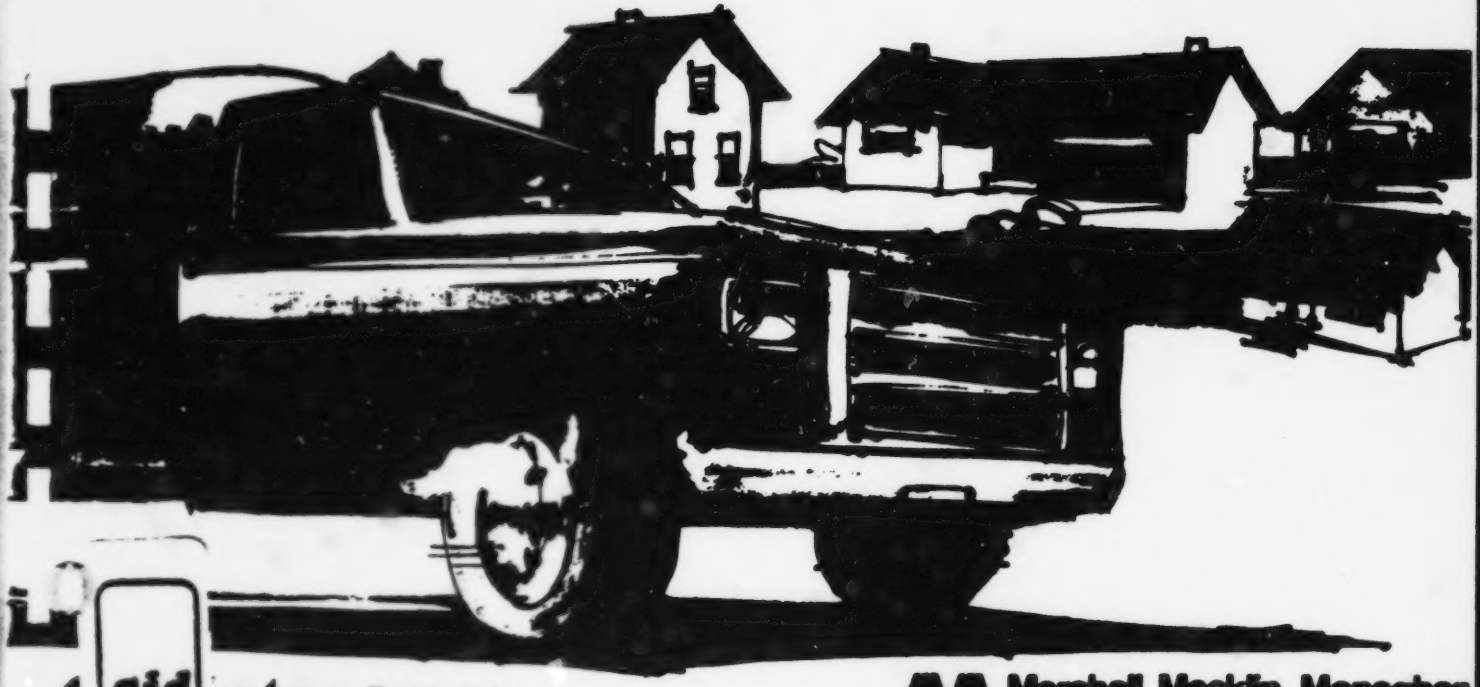


URBAN TRAFFIC NOISE POLICY STUDY
STAGE 1: A Perspective



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Dear Sir

We are pleased to submit our report entitled "Urban Traffic Noise Policy Study-Stage 1" for the City of Edmonton.

The report includes a review of the social-environmental, economic and health related impacts of traffic noise, a survey of existing residential noise standards in use throughout North America and Europe and a preliminary assessment of arterial roadway traffic noise levels within the existing residential areas in the City of Edmonton.

This information forms a basis for a refined Stage II analysis which will focus upon related policy issues, the need for noise attenuation and financing and from which a decision will be made on preferred residential noise level standards.

We wish to thank the Transportation Systems Design Department for the co-operation received and for the opportunity of working on this assignment.

Yours very truly

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- Mr. M.F. Palmer, Planning Supervisor, Transportation Systems Design Department, City of Edmonton, who co-ordinated the day to day efforts, provided the necessary liaison between the Steering Committee, City staff and the Consultant and who was, in chief, responsible for all facets of computer programming.

- Mr. G. Latham, Acting Director of Project Planning Services, Transportation Systems Design Department, City of Edmonton, who provided additional guidance and leadership.

- Mr. D. Thomson, Public Health Educator, Health Department, City of Edmonton and members of the Health Department staff for the preparation and submission of their report "Health Effects of Traffic Noise - A Literature Review."

- Mr. H. Gidamy, Head Noise Pollution Control Section, Pollution Control Branch, Ontario Ministry of the Environment who contributed to all aspects of the study ensuring a high standard of quality and the accuracy of technical content.

- All members of the Steering Committee.

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APPENDICES

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B - Barrier Case Studies; An Annotated Bibliography

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D - City of Edmonton Health Department Report - "Health Effects of Traffic Noise"

1. Introduction and Summary

1. INTRODUCTION AND SUMMARY

1.1 Background and Study Objectives

The City of Edmonton initiated an Urban Traffic Noise Policy Study to develop preferred residential noise level standards. The study design was established by the City of Edmonton Transportation Systems Design Department with assistance provided by a Consultant Review Panel and it is divided into three stages as follows:

Stage I, involves the development of basic understanding of the social-environmental, economic and health impacts of traffic noise on residential land uses; the identification of existing residential noise standards, policies and guidelines in use throughout North America and Europe; and a preliminary assessment of arterial roadway traffic noise levels within existing residential areas in the City of Edmonton aimed at narrowing the range of potential standards and identifying related policy implications and costs.

Stage II, involves a refinement of the Stage I analysis focussing attention on related policy issues, the need for noise attenuation, the alternative means available for attenuation and financing for a final decision on preferred residential noise level standards within both existing and future residential areas.

Stage III, involves follow-up and supportive studies related to urban traffic noise policy.

1.2 Study Organization

Marshall Macklin Monaghan Limited was retained by the City of Edmonton Transportation Systems Design Department on February 27, 1980, to carry out Stage I of the Urban Traffic Noise Policy Study.

The investigation was conducted under the overall direction of the City of Edmonton Transportation Systems Design Department. Additional guidance was provided by a Steering Committee consisting of the following representatives:

- Mr. G. Latham, Acting Director of Project and Planning Services, Transportation Systems Design Department, City of Edmonton.
- Mr. M. Palmer, Planning Supervisor, Transportation Systems Design Department, City of Edmonton.
- Mr. K. Sawatzky, General Supervisor - Special Projects, Design Section, Engineering Department, City of Edmonton.
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- Mr. S. Slobodian, Testing Engineer, Engineering Department, City of Edmonton.
- Mr. D. Thomson, Public Health Inspector/Health Educator, Health Department, City of Edmonton.
- Mr. S. Quiring, Manager, Program Development, Alberta Transportation.
- Mr. A. Schultz, Section Head, Air Quality Control Branch, Alberta Environment.

This report presents the findings of the Stage I component of the Urban Traffic Noise Policy Study.

1.3 Procedures

An in depth literature search of over 100 documents was undertaken to develop a basic understanding of the social-environmental and economic impacts of traffic noise on residential land uses and to identify existing noise standards, policies and guidelines in use throughout North America and Europe. The findings of the literature review were supplemented by additional information gathered from twenty-four telephone interviews conducted with various levels of government in Canada and the United States and from a mailed questionnaire survey designed and processed by the City of Edmonton.

Supplementary information concerning health impacts of traffic noise was gathered and submitted by the City of Edmonton Health Department in a document entitled "Health Effects of Traffic Noise - A Literature Review". A copy of the Health Department document is incorporated as an appendix to this report.

A preliminary assessment of arterial roadway traffic noise was undertaken as a first order attempt to narrow the range of potential residential noise standards. The assessment consisted of an investigation of traffic noise levels at the ground storey for all existing residential densities and of the effectiveness of noise barriers in reducing the traffic noise within the areas to selected design levels.

The intent of the study was not to suggest that noise barriers are the only means of attenuating unwanted sounds. In fact there are a number of available alternatives including traffic management, architectural treatment, double glazing and air conditioning of residential units. The intent of the study was simply to illustrate the need for and magnitude of noise attenuation requirements at alternative design standards as well as to focus attention on associated implications such as cost and alternative means of attenuation.

Traffic noise levels on all arterial roads within existing residential areas were estimated using 1980 traffic volumes and the prediction techniques outlined in the Alberta Surface Transportation Noise and Attenuation Study. Noise levels are expressed in terms of a single description, an A-weighted energy equivalent day-night sound level, dBA Ldn. This description is derived by averaging time varying sound energy over the daytime (7 a.m. - 10 p.m.) with the time varying sound energy over the nighttime (10 p.m. - 7 a.m.) to which an additional ten decibel weighting is applied.

The number of persons living adjacent to each arterial road was determined using land use data from the Transportation System Plan.

Five alternative noise levels were selected as potential residential noise standards. These levels are identified as 55, 60, 65, 70 and 75 dBA, Ldn. For each level, the number of persons exposed to excess noise after the implementation of barriers was estimated; the required length of barriers was determined; program costs were established; and benefits accrued were identified.

1.4 Summary of Findings

1.4.1 - Traffic Noise Impacts

To varying degrees, persons residing adjacent to arterial roads are all subject to social-environmental, economic and health related traffic noise impacts. Social and environmental noise impacts include interference with speech and communications, interference with sleep and interference with recreational activities generally of a passive nature.

Economic related impacts include decreased property values or costs associated with noise attenuation.

Health related impacts may involve both physiological as well as psychological responses causing either temporary or permanent hearing loss, reduced performance capability or undesirable behavioural effects. In general, such reactions are unlikely to occur as a result of traffic noise except with prolonged exposure.

Presently, there is little quantitative data available in the literature on the effects of traffic noise on health or economic related impacts. However, significant information on the social-environmental effects related to traffic noise has been collected via numerous social surveys. These impacts are presented in Table 1.1. Also shown, for comparison purposes, are estimates of the number of formal complaints to be encountered at various noise levels based on data accrued from surveys of resident responses to aircraft noise.

Table 1.1
Summary of Social Survey Results

Noise Level (dbA, Ldn)	Percent of Population Likely To Report			
	Speech Interference	Sleep Interference	High Annoyance	Formal Complaints
55	0-3%	5%	0-3%	0
60	4-10%	10%	0-10%	0
65	5-18%	15%	8-17%	0
70	9-24%	20%	16-24%	0-2%
75	18-32%	25%	25-34%	3-7%

1.4.2 - Existing Noise Level Standards

To minimize the significance of traffic noise related impacts, Governments, Government Agencies, and communities throughout North America and Europe have established, on an individual basis, recommended sound level policies governing new residential development, redevelopment of existing residential areas, retrofit programs and new sources of noise.

Presented in Figure 1.1, is a summary of existing noise level standards, in use elsewhere, compiled on the basis of information readily available in the open literature. For ease of comparison, all standards have been converted to the day-night sound level dBA, Ldn.

As illustrated there is considerable variation among the standards. Most jurisdictions do not administer a comprehensive noise control program. Those who do, include the Province of Ontario and the State of California. Many jurisdictions do not possess direct legal means for the enforcement of noise controls and instead rely upon general provisions contained within other acts or guidelines. For example, the Ontario Ministry of the Environment and Sweden both rely upon general provisions set out under planning guidelines.

Figure 1:1 Existing Design Noise Levels

JURISDICTION	CURRENT STATUS		FINANCING INVOLVED	APPLICATION				SOUND LEVEL - dBA, Ldn
	LEGAL REQUIREMENT	GUIDELINE		RETROFIT	NEW RESIDENTIAL DEVELOPMENT	NEW NOISE SOURCES	SPECIAL USES	30 40 50 60 70 80
Canada Mortgage and Housing Corporation (CMHC)	●		●		●		Living Rooms	
Government of ONTARIO Freeway Noise Policy	●			●	●	●		
ONTARIO Ministry of the Environment		●			●		Living Rooms Bedrooms	
U.S. Environmental Protection Agency (E.P.A.)		●		●	●	●		
U.S. Housing and Urban Development (H.U.D.)	●		●		●			
U.S. Federal Highway Administration (FHWA)	●		●	●		●		
CALIFORNIA Noise Insulation Standards	●				●			
CALIFORNIA Regulation on Freeway Noise	●			●			Classrooms and Libraries	
SWEDEN Board of Urban Planning		●			●			
HAWAII Community Noise Regulations	●			●			Classrooms, Hospitals and Libraries	
DENMARK Guidelines		●			●		Rural Suburban City	
JAPAN Environmental Quality Guidelines		●			●		Hospitals	
SWITZERLAND Highway Noise Guidelines		●			●	●	Daytime Nighttime	
FRANCE Road Traffic Noise Control Guidelines		●			●	●		
UNITED KINGDOM Land Compensation Regulations	●		●	●		●		
NETHERLANDS		●		●	●	●	New Highway New Development Existing Development	

LEGEND

Objective — Discretionary — Unacceptable

OUTDOORS

INDOORS

Whereas most jurisdictions address general land uses, some jurisdictions emphasize the need for noise control of special uses. For example, both the State of California and the State of Hawaii require the control of excess noise within classrooms and libraries. Financing of noise attentuation is generally controlled by authorities at the Federal or State level eg. CMHC and FHWA. The United Kingdom is the only jurisdiction identified which provides compensation due to traffic noise and this compensation is provided only after the applicant satisfies very stringent conditions.

In general, the objective outdoor noise levels set by the majority of jurisdictions range between 55 and 60 dBA, Ldn and most identify levels in excess of 65 dBA, Ldn to be unacceptable. Many jurisdictions also provide standards for indoor noise control. Of those surveyed, the majority identify acceptable levels to be those not exceeding 45 to 50 dBA, Ldn.

1.4.3 - Population Exposure to Traffic Noise

As illustrated in Table 1.2, approximately 130 000 persons or 23 percent of the City of Edmonton population currently reside adjacent to arterial roads. Of these, approximately 18 500 persons are exposed to outdoor noise levels less than or equal to 55 dBA Ldn, and approximately 16 500 persons are exposed to outdoor levels ranging between 55 and 60 dBA, Ldn. The remaining 95 000 persons are exposed to outdoor levels ranging between 60 and 75 dBA, Ldn.

The implementation of a barrier retrofit program at a design level of 55 dBA, Ldn would result in the following changes. Approximately 43 000 persons would be exposed to outdoor noise levels less than or equal to 55 dBA, Ldn, approximately 28 000 persons would be exposed to outdoor levels ranging between 55 and 60 dBA, Ldn and approximately 59 000 persons would be exposed to outdoor levels ranging between 60 and 75 dBA, Ldn.

Table 1.2

Estimated Population Exposed to Arterial Roadway Traffic Noise

	1980 Traffic Noise Levels (dBA, Ldn)						
	55 or less	55-60	60-65	65-70	70-75	Greater Than 75	Total
Current Conditions	18 500	16 500	44 000	28 500	22 500	0	130 000
With a Barrier Retrofit Program Designed to Reduce Noise to:							
55 dBA, Ldn	43 000	28 000	30 000	16 500	12 500	0	130 000
60 dBA, Ldn	18 500	33 000	49 500	16 500	12 500	0	130 000
65 dBA, Ldn	18 500	16 500	51 500	31 000	12 500	0	130 000
70 dBA, Ldn	18 500	16 500	44 000	28 500	22 500	0	130 000
75 dBA, Ldn	18 500	16 500	44 000	28 500	22 500	0	130 000

Similar changes would be affected via the implementation of barrier retrofit programs at design levels of 60 and 65 dBA, Ldn. No changes would likely be effected if the selected noise design level were 70 dBA, Ldn or greater. As shown in Table 1.2, levels in excess of 70 dBA, Ldn represent current conditions.

1.4.4 - Barrier Retrofit Program Characteristics

Barrier retrofit program characteristics for each of the alternative noise policy levels are summarized in Table 1.3. A retrofit program implemented at a design level of 55 dBA, Ldn would entail the construction of approximately 98 kilometres of barrier and would cost approximately $37 million. A retrofit program implemented at a design level of 60 dBA, Ldn would entail the construction of approximately 59 kilometres of barrier and would cost approximately $18 million. Similarly, a retrofit program implemented at a design level of 65 dBA, Ldn would entail the construction of over 27 kilometres of barrier and would cost approximately $6 million.

The rational for providing this information is to present a first approximation of the magnitude of both the noise attenuation requirements and the program costs at alternative design standards. It is not to suggest that such a barrier retrofit program be carried out as the sole means of noise attenuation. Other actions which may be employed include traffic management and control, building modifications, etc., and it is anticipated that such issues would be addressed within Stage II of this study.

If the implementation of barriers within existing residential areas is to play a part within an overall noise retrofit program it would be necessary to establish a barrier priority scheme by which to allocate funding and to identify the locations where they should be installed and the order of priority in which they should be installed. Such priority schemes are described within Section 4.3 of this report.

Table 1.3
Barrier Retrofit Program Characteristics

Noise Policy Level (dBA,Ldn)	Length of Barrier (Kilometres)				Cost of Barrier ($ Millions)
	3.0 Metres High	4.5 Metres High	Greater Than 4.5 Metres High	Total	
55	38.5	32.0	27.3	97.8	37.0
60	32.0	27.3	-	59.3	17.6
65	27.3	-	-	27.3	5.8
70+	-	-	-	-	0.0

1.4.5 - Barrier Retrofit Program Effectiveness

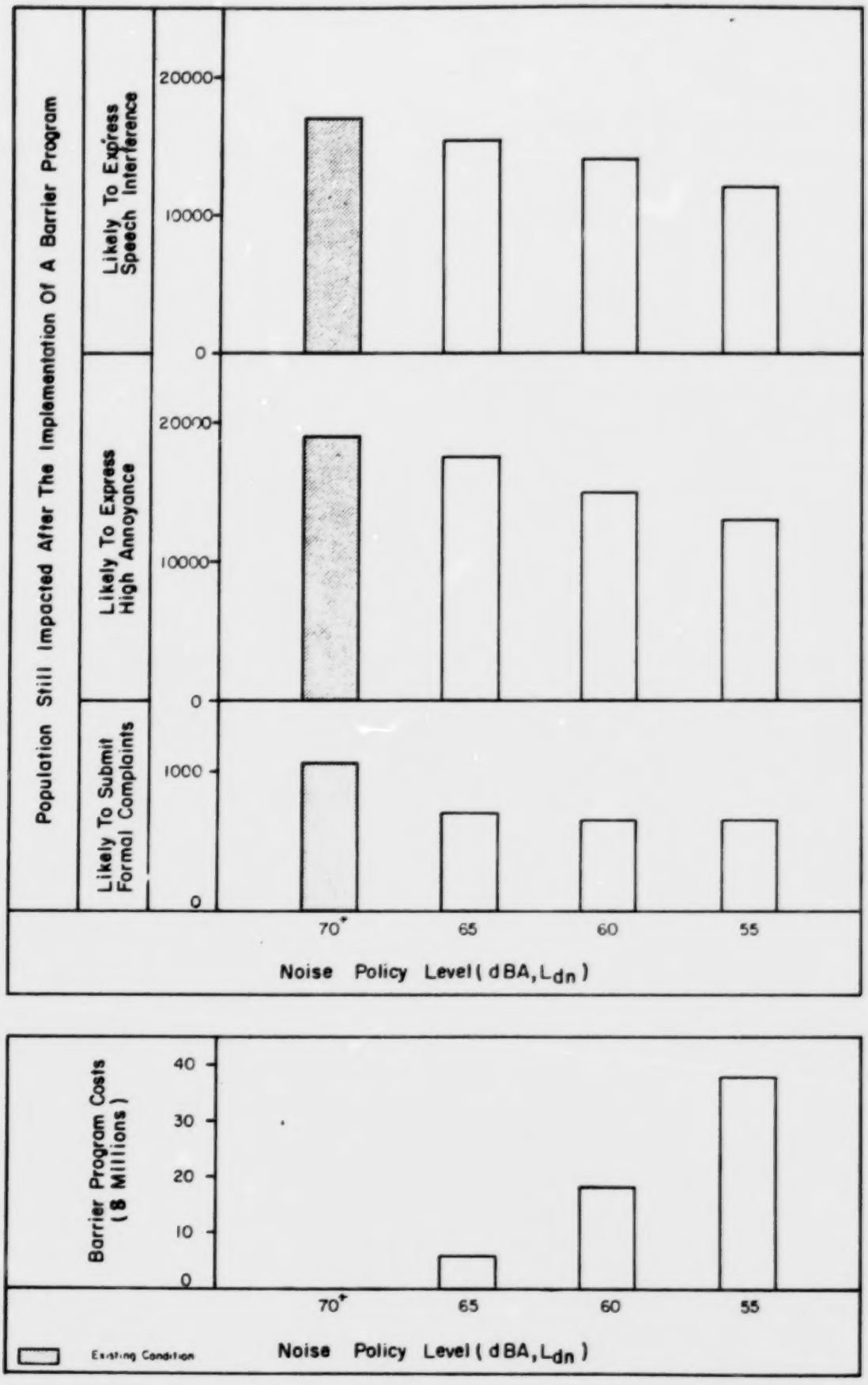
The significance of the social and environmental impacts for each of the five policy standards investigated was derived by applying the relationships reported in Table 1.1 to the populations presented in Table 1.2.

Two specific noise impacts are reported herein. These are interference with speech and interference with recreational activities. The two are addressed within this report because they are specifically associated with the traffic noise levels simulated by the Transportation Systems Design Department ie; outdoor noise levels at the ground storey. The results are presented in Figure 1.2.

A noise policy standard of 70 dBA, Ldn or greater represents the current or Status Quo situation. Should a survey be taken of the population residing adjacent to arterial roads, approximately 17 000 persons are likely to express interference with speech outdoors, and approximately 19 000 persons are likely to express a high degree of annoyance due to interference with social or recreational activities. Of these, it is estimated that approximately 1 100 persons are likely to submit formal complaints to the City staff.

Should a barrier retrofit program be implemented for a design standard of 65 dBA, Ldn, at a cost of approximately $6 million, it is estimated that the number of persons reporting speech interference, high annoyance or submitting formal complaints would be reduced to approximately 16 000, 17 000 and 700, respectively. These figures represent reductions of six, eleven and 36 percent, respectively.

Similarly, should a barrier retrofit program be implemented for a design standard of 60 dBA, Ldn at a cost of approximately $18 million, an incremental increase of $12 million (200 percent), it is estimated that the number of persons reporting speech interference, high annoyance or submitting formal complaints would be reduced to approximately 14 000, 15 000 and 600 respectively. These figures represent incremental reductions of 13, 13 and 14 percent respectively.



Comparison Of Policy Impacts

Fig. 1.2

Similar reductions are expected as a result of a barrier retrofit program designed at a policy standard of 55 dBA, Ldn. This is the most stringent of the policy levels examined and a barrier retrofit program implemented at this policy level would cost approximately $37 million.

Two major restrictions limit the effectiveness of a barrier retrofit program. The first is the limited benefit to be accrued for the substantial costs involved.

As previously outlined the benefits to be accrued by selecting a policy level of 65 dBA, Ldn over that of 70 dBA, Ldn are in the order of six to 36 percent reductions in negative reactions. The cost increases from zero to $6 million. Similarly, the benefits to be accrued by selecting 60 dBA, Ldn over that of 65 dBA, Ldn are in the order of 13 to 14 percent. The cost increases from $6 million to $18 million. Further marginal benefits may be gained by selecting a policy level of 55 dBA, Ldn. However the cost increases to $37 million.

The second restriction is that the effectiveness of a barrier retrofit program is generally limited to the ground storey. Such is the case in this study. The Stage I study design did not provide for the simulaton of noise or barrier heights and costs for levels above the ground storey, although in fact, barriers may occasionally be constructed high enough to provide attenuation at the second storey.

Whereas, barriers may offer an effective means for protecting both low density single storey dwellings and the ground floor of medium or high density multiple storey dwellings, in general, other means of noise attenuation are usually employed for the protection of medium and high density multiple storey dwellings. These other measures may include traffic management and control, building modification and air conditioning.

Since the Stage I study design did not provide for the simulation of noise levels above the ground storey, it was not possible to investigate associated issues such as interference with sleep, health effects and economic impacts at this time.

Policies and actions that can adequately deal with these issues can more appropriately be dealt with in Stage II of the study where such factors as traffic management and control, building modifications etc., are to be investigated.

2. Traffic Noise Impacts

2. TRAFFIC NOISE IMPACTS

The methods by which various social indicators may be employed to measure and assess the potential impact of roadway noise on adjacent residential communities are discussed in this part of the report.

Several key studies are highlighted with the prime objective being to derive conclusions and recommendations for later use in evaluating the significance and impacts of road noise levels.

The impacts and the sections within which they are addressed are as follows:

2.1 Interference With Speech
2.2 Interference With Sleep
2.3 Annoyance and Complaints
2.4 Health Effects
2.5 Economic Impacts

A brief summary of these effects is presented in Section 2.6.

2.1 Interference With Speech

Speech in the presence of noise can be difficult or even impossible to understand because of the masking effect on some or all of the speech sounds.

The degree to which noise disturbs speech depends not only on physical factors such as noise levels, vocal effort, distance between speakers, and room acoustics, but also on non-physical factors such as the familiarity of the listener with the speaker's vocabulary and accent, the topic of conversation, the listener's motivation, and the hearing acuity of the listener.

Conversational speech is much more easily understood in noisy surroundings as compared to instructions or requests for assistance.

2.1.1 - Measurement of Speech Interference

Estimating speech intelligibility on the basis of physical measurements has been the subject of many research studies. Methods generally used to estimate speech intelligibility are described as follows(1):

(a) The Articulation Index (AI) is the most accurate method of rating speech intelligibility. The Articulation Index predicts speech intelligibility in the presence of steady-state noise and can be adapted to predict the intelligibility of speech in the presence of fluctuating noise levels. Unfortunately, the complexity of the calculation procedure limits its usefullness in the measurement and monitoring of noise levels on a routine basis.

(b) The Speech Interference Level (SIL) is a relatively simple numerical method for estimating speech-interference on the basis of general voice level and distance between communicators. For steady-state noises, the Speech Interference Level is a reasonably accurate predictor of the relative ranking of noises with respect to their speech-interfering properties.

(c) The sound level measured in dBA is a simple alternative for estimating the potential interference with speech and communications by specific noise sources. It is an overall measurement of all components of sound with special weighting of the middle frequencies to simulate the way in which the human ear responds to sounds of different frequencies. The A-weighted sound level can be read directly from a sound level meter, or alternatively can be estimated with the use of reliable models, and has been found to correlate well with people's judgement of the loudness or annoyance of many kinds of noise, including road traffic.

(1) A comprehensive discussion of the relative importance and difference between various indices is presented by Kryter in his report on The Effects of Noise on Man - Reference No. 43.

2.1.2 - Speech Interference Outdoors

Figure 2.1 presents the distance between speakers for satisfactory outdoor communications under differing steady background noise levels, for three degrees of vocal effort: communications under relaxed conversation, normal, and raised voice "satisfactory conversation".

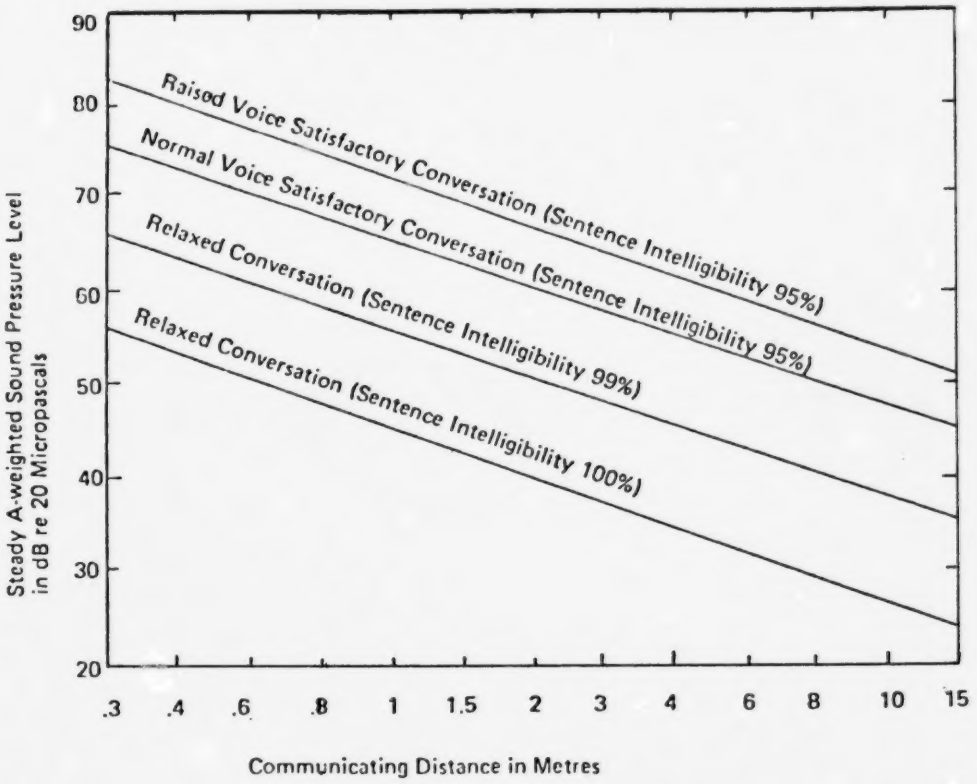


Figure 2.1
Maximum Communication Distances Outdoors
(Ref: 90)

The levels shown for relaxed conversation permit perfect speech intelligibility when communicating in a normal voice. This situation represents an ideal environment for communication indoors.

The levels shown for normal and raised voice "satisfactory conversation" permit 95 per cent sentence intelligibility which is generally considered adequate for outdoor communication.

2.1.3 - Speech Interference in the Presence of Time-Varying Sound Levels

The data shown in Figure 2.1 reflects the results of steady background levels. For high volumes, under free flow conditions, traffic noise is fairly uniform and may be characterized as essentially steady. However, as the ratio of trucks to cars increases or the number of vehicles on the roadway decreases, traffic volume fluctuations increase and are regarded as time varying.

Studies have concluded that almost all time-varying environmental sounds with the same equivalent sound level, averaged over long time periods, lead to better intelligibility than that of steady sounds. In other words, for an equal average level, road traffic noise may produce less total speech interference than a continuous steady noise. On the other hand, during those times when the higher level noises occur such as during a truck passby, the speech interference would be greater than its average value.

Consequently the relationships illustrated in Figure 2.1 can be used to estimate the significance of traffic noise impacts, with the added note that such estimates are on the conservative side.

2.1.4 - Speech Interference Indoors

The impact of traffic noise on speech and communications indoors is based on sound levels projected outside minus 10 dB to account for differences between outdoor and indoor sound levels assuming normal building construction and windows open.

As shown in Figure 2.2, the maximum background sound level that will permit relaxed conversation with total sentence intelligibility throughout a room is 45 dBA (55 dBA outdoors assuming windows open). A level of 55 dBA (65 dBA outdoors assuming windows open) permits an average sentence intelligibility of 98 percent. This data is based on speech interference in the presence of steady noise without noticeable fluctuations.

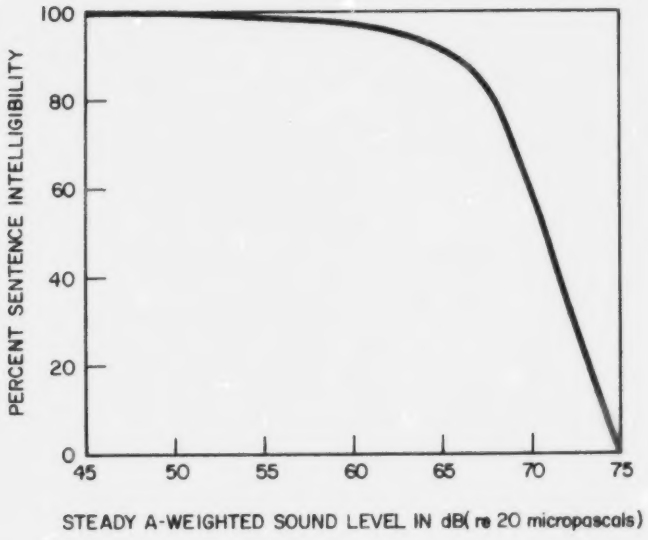


Figure 2.2
Indoor Communication Intelligibility
(Ref: 90)

2.1.5 - Speech Interference and Annoyance

Thus far, speech interference has been discussed with regards to percentage sentence intelligibility. However, a person might be able to communicate at 98 percent sentence intelligibility but be very annoyed with the kind of background noise or the ambient level. This aspect of speech interference as studied through attitudinal and social surveys is reviewed in Section 2.3 of this report.

2.2 Interference With Sleep

Interference of noise on sleep may be categorized as arousal from sleep, prevention from falling asleep, and interference with sleep which is already in progress.

Variables known to affect responsiveness to noise during sleep include: age and sex of subjects, motivation, time asleep, sleep stages, pre-sleep state, intensity and duration of the noise stimulus, its frequency spectrum, its meaningfulness, and the number of occurrences per night.

2.2.1 - Sleep Classification

Sleep is classified into five stages according to EEG (Electroencephalogram) waveform and to rapid eye movement (REM).

Generally, in Stage I, one is drowsy but awake. In late Stage I one drifts back and forth between waking and sleeping. Stages II, III and IV represent definite sleep. In the fifth stage, known as REM sleep, most dreaming and mental activities take place.

2.2.2 - Results of Surveys Related to Traffic Noise

Much of the information on effects of noise on sleep comes from experiments conducted in laboratories.

Low traffic volumes are reported to be more disruptive of sleep than high volumes. This would indicate that the fluctuation of the noise levels is a significant factor in determining sleep interference, and that noise descriptors which are based on averages, such as Leq and Ldn do not accurately predict these adverse responses.

The time required to fall asleep is reported to be longer with traffic noise present.

Findings indicate that subjects who sleep well at 35 dBA, complain about sleep disturbance and have difficulty in falling asleep at 40 to 50 dBA. In the presence of traffic it may take subjects over an hour to fall asleep initially, and awakening may occur often during sleep. Such data derived from experimental laboratories formed the basis for the EPA study[1] recommendation that a maximum allowable limit of 30-35 dBA be used for noise inside dwellings.

The results of a Canadian study reported in 1969[2] suggest that the probability of subjects being awakened by a peak sound level of 40 dBA is five percent, increasing to 30 percent at 70 dBA. The probability of subjects reverting to an earlier sleeping stage, as defined by EEG, is 10 percent for a peak sound level of 40 dBA, and 60 percent for 70 dBA.

(1) Refer to the U.S. Environmental Protection Agency report on Public Health and Welfare Criteria for Noise, July 1973 - Reference 92.

(2) Results from a study conducted by G.J. Thiessen on the Effects of Noise During Sleep - Reference 81.

Figure 2.3 shows results of recent Canadian work[1] on probability of shift in sleep level versus peak noise level in dBA. The study is based on 35 people subjected to recorded truck noise passbys seven times per night. The noise measured was from a truck travelling at 90 km/h past a recording station located 15 metres from the line of travel. Also illustrated are the results of other studies on sleep disturbance with the use of various stimulus durations. For stimulus of long duration the probability of subjects waking is much higher as intuitively expected.

This study also investigated, in a limited fashion, adaptation to noise intrusions during sleep. Subjects appeared to overcome inability to sleep on the second and succeeding nights. However, the quality of sleep, based on EEG patterns, was not identical with that in the pre-noise period.

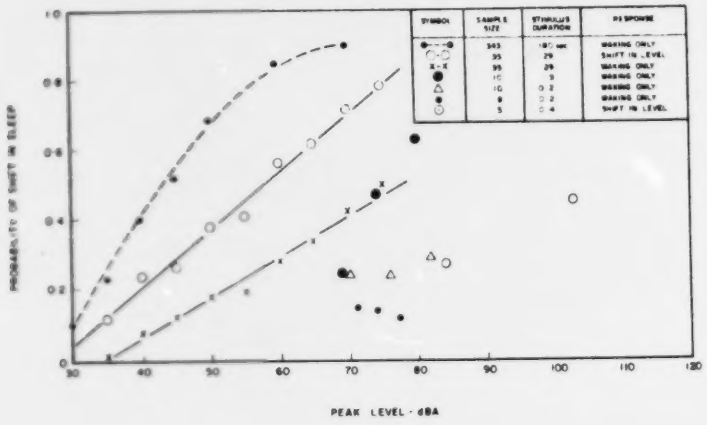


Figure 2.3
Comparison of Laboratory Studies of Sleep
(Ref: 80)

(1) Refer to the report prepared by Wyle Laboratories on Community Noise - Reference 99.

The study also concluded that continuous interference of sleep over time has deleterious effects on subjects, which was then verified by the Griefhan Model. Both studies are contained in the City of Edmonton Health Department Report, found in Appendix D.

2.2.3 - The Selection of Criteria for Assessing Sleep Disturbance

The problems of selecting criteria for gauging the effects of noise on sleep has been the subject of much discussion. So far, the choice is not clear.

It is suggested that two criteria would be reasonable. The first would be to limit sleep disruption to less than one change in sleep stage. The alternative would be to limit the frequency of awakening. Lukas[1] suggests that a conservative policy would be to limit noise levels indoors so that the response to noise are limited to EEG changes of less than one sleep stage. Furthermore, he suggests the use of the Effective Perceived Noise level in decibels, (EPNdB) or alternatively the Effective Sound Level in A weighted decibels, (EdBA).

Noise levels indoors must be maintained below 70 EPNdB if there is to be little or no probability of disturbing sleep. At a level of 90 EPNdB there is a 50 percent chance that someome will be disturbed.

The study of the effects of noise on sleep is severely hampered by a lack of knowledge about the sleeping process and its importance to the body. With the data available it is not possible to state definitively the effects of loss of sleep or interuption of sleep on an individual's health, except in the most extreme cases. A common sense type approach based on everyday experience indicates that sleep is needed, and that lack of sleep has adverse effects on people.

(1) Refer to the report on Noise and Sleep: A Literature Review and a Proposed Criterion for Assessing Effect by J.S. Lukas -- Reference 46.

Presently, little laboratory information is available on the effects of fluctuating noise on sleep, typical of nighttime vehicular traffic on roadways. However, the effects of steady sound of a specific magnitude and duration on the percentage of awakening and probability of shift in sleep level do exist. This information can then be used to estimate the approximate effects of roadway traffic noise on sleep.

2.3 Annoyance and Complaints

Annoyance in residential areas caused by noise from road traffic has been recognized as a social problem.

The degree of annoyance and whether that annoyance leads to complaints, or action against a controlling agency or jurisdiction are dependent on many factors including the nature of the sounds, the activities that are disturbed and the physiological reactions of the exposed receivers. Several surveys have been carried out in an attempt to discover a relationship between the annoyance felt by a community and the level of traffic noise to which it was exposed.

2.3.1 - Methods for Assessing Annoyance

In general, there are two basic methods for assessing annoyance and community response to noise:

(a) Case Histories: Case history data are usually collected when there are complaints about particular noise sources. Such process involves the collection of sound levels at the complainants' locations, data concerning the nature and extent of the noise source, as well as the individual subjective reaction of those complaining about the noise.

(b) Social Surveys: The social survey is a more elaborate version of the case history. Social surveys include activities such as measurement of the sound levels, interviews with the general population, investigation of records of complaints, and statistical analysis of the measurements and interview responses.

Sounds are generally referred to as unwanted noise when they intrude or interfere with some activity. There is a great deal of variability among different people with respect to their perception or awareness of different noises and their tolerance of them. In order to understand this variability and to assess the most appropriate methodology for measuring it, social surveys commonly address the following four aspects:

- Perception or awareness of the noise stimulus.
- Activities affected or interrupted.
- Annoyance resulting from the interruption.
- Complaints resulting from the annoyance.(1)

2.3.2 - Review of Social Surveys Related to Traffic Noise

(a) The Alberta Surface Transportation Noise and Attenuation Study(2) reviewed the results of nine social surveys related to road traffic noise carried out between 1961 and 1973. On the basis of the review it was concluded that noise ratings more complicated than the A-weighted sound level were not justified.

(b) A recent published report entitled "Noise in the Human Environment" by Environment Council of Alberta(3) presents a review of current social surveys. Subjects which are addressed include interference with speech communication, sleep

(1) For additional information concerning the philosophy and methodology of conducting social surveys the reader is referred to reports by J.D. Chalupnik, on Transportation Noise - A Symposium on Acceptability Criteria - Reference 18, A. Alexander et al on Road Traffic Noise - Reference 3, and J.D. Miller's Effects of Noise on People - Reference 51.

(2) Refer to the study conducted by De-Leuw Cather entitled Alberta Surface Transportation Noise and Attenuation Study - Reference 23.

(3) Refer to the study by the Environment Council of Alberta on Noise in the Human Environment - Reference 29.

disturbance, interference with listening to radio or watching television, and the percentage of community respondents indicating high annoyance to varying noise levels. The percentage of people disturbed or highly disturbed is presented as a function of Leq and Ldn.

The report concludes that interference with sleep should provide the basis for setting acceptable nighttime noise levels. However, it is recognized that there is insufficient data concerning the interference of nighttime traffic noise on sleep. Further it is suggested that the use of two sound level descriptors such as an energy equivalent level and a peak level would be desirable.

The report also concludes that interference with speech communication should provide the basis for setting acceptable daytime noise levels. It is further suggested that the percentage of people highly annoyed is a subjective parameter and it cautions against its use without consideration of site specific parameters.

(c) Schultz, in his report entitled "Synthesis of Social Surveys on Noise Annoyance", analyzed the results of more than 18 social surveys on annoyance due to transportation noise(1). The data reviewed included the noise of aircraft, street traffic, expressway traffic, and railroads. The results of 11 of these surveys showed a remarkable consistency. However, the procedure and results drew severe criticism from several sociologists who argued that Schultz exercised an unacceptable amount of subjective judgement in translating basic and fundamental data. The data is presented in Figures 2.4 and 2.5. Others have argued that Schultz's data represents a "universal" response which may also be applicable to community noise of other kinds. For

(1) Refer to the report on the Synthesis of Social Surveys on Noise Annoyance by T.J. Schultz - Reference 75.

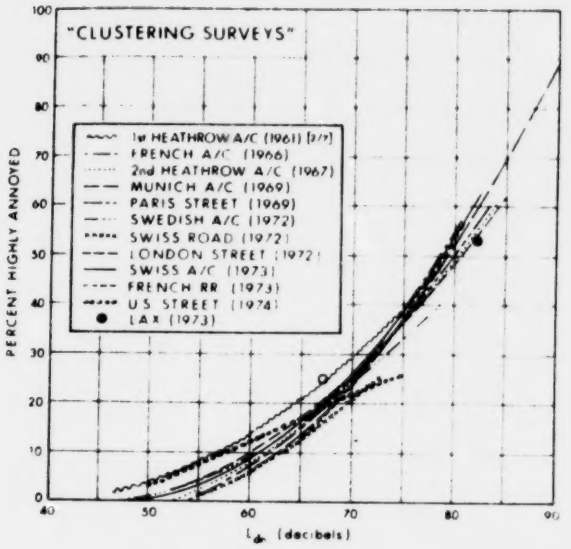


Figure 2.4
Summary of Annoyance Surveys
(Ref: 75)

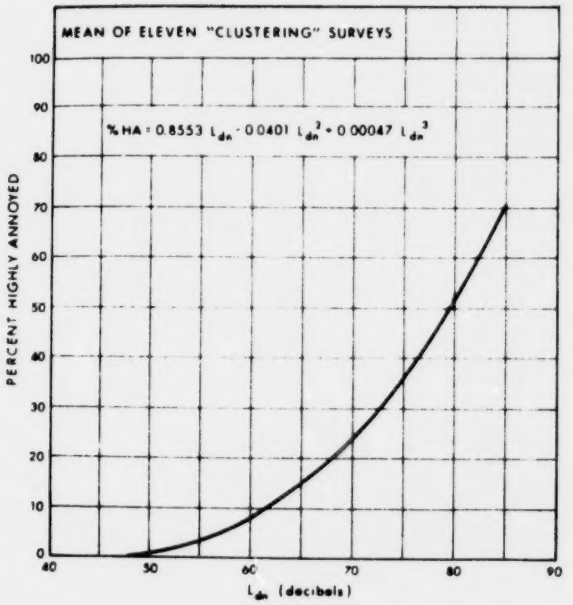


Figure 2.5
Public Annoyance Due to
Transportation Noise
(Ref: 75)

example, the 1977 recommendations made by the U.S. National Research Committee on Hearing, Bioacoustics and Biomechanics (CHABA) were based on Schultz's findings.

(d) A survey of data relating annoyance to street traffic noise, presented in a recent paper prepared by the National Research Council (NRC) of Canada[1] as background information on the noise standards adopted by Canada Mortgage and Housing Corporation (CMHC) is illustrated in Figure 2.6.

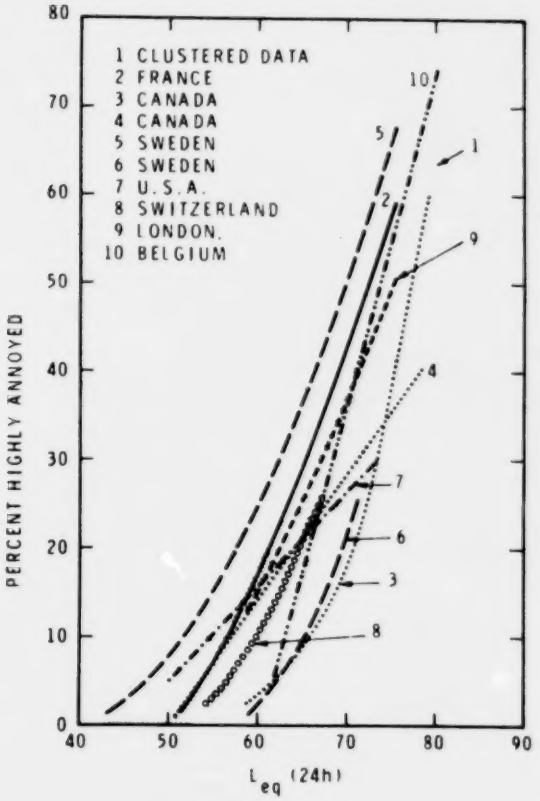


Figure 2.6
Reported Annoyance Due to
Street Traffic Noise
(Ref: 55)

(1) Refer to the paper on Residential Planning with Respect to Road and Rail Noise, by Northwood, T.D., et al - Reference 55.

The NRC concluded that an outdoor level of 55 dBA Leq represents the threshold level at which significant annoyance begins and that the percentage of people annoyed by outdoor noise increases sharply when the Leq (24 hour) outside dwellings exceeds that level. It was also concluded that for typical dwellings with openable windows, a 55 dBA outdoor level would correspond to 40 - 45 dBA indoors which is also a threshold level above which one could expect interference with such indoor activities as listening to conversation or music.

(e) A major study conducted by Bradley and Jonah[1] in 1977 was designed to assist the Road and Motor Vehicle Traffic Safety Branch of Transport Canada in developing criteria for vehicle noise levels, through a better quantitive understanding of adverse responses to traffic noise.

They selected 44 sites from amongst the following communities: small towns (Ingersoll, Tillsonburg and Beachville), medium sized (London) and large municipalities (Metropolitan Toronto and the City of Mississauga).

Measurements were taken at each site using noise monitors that recorded road traffic sound levels over several days including weekdays and weekends. At each site 25 subjects were interviewed using an extensive questionnaire designed to obtain response data on basic demographic information, personality measures and to determine possible health impairment due to traffic noise.

The following are some of the findings which may be of interest to the study at hand:

1) As traffic noise levels increased, the percentage of people who claimed to be "very annoyed" and "very interfered" with by traffic noise also increased.

(1) Refer to the Field Study of Human Response to Traffic Noise by Bradley and Jonah - Reference 11.

2) On the basis of 300 responses, it was observed that apartment dwellers were more likely to be very annoyed with traffic noise than other subjects residing in single detached and row houses. Further, there was also a tendency for more apartment dwellers to report that some of their activities such as sleep were very interfered with compared to the other subjects.

3) People living adjacent to freeways reported annoyance more frequently than those living on arterial roads, thus reflecting the influence of the relatively higher nighttime sound levels. Based on 400 responses, high socio-economic status subjects (SES) reported more annoyance and interferrence than low SES subjects at the freeway sites. Adjacent to other roads, low SES subjects were more interfered with than high SES subjects.

4) Of 600 responses, people living in smaller communities expressed less annoyance and interference of traffic noise.

5) Speech interference showed greater disturbance than other interference responses at higher sound levels, and that most other activities are similarly interfered with as a function of traffic noise level.

6) The percentage of the subjects who reported a high degree of annoyance with traffic noise at each site is plotted against the site average traffic noise level in Figure 2.7. Also shown is the percentage of subjects reporting sleep interference and speech disturbance.

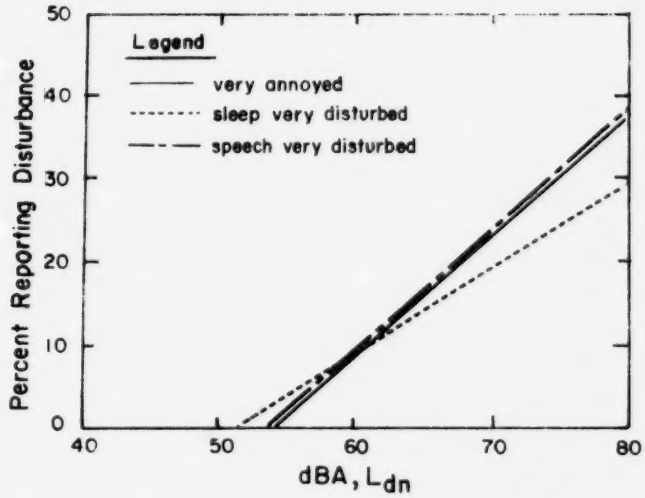


Figure 2.7
Summary of Survey Conducted
For Transport Canada
(Ref: 11)

At 65 dBA Leq approximately 23 percent of the subjects reported being very annoyed. Nineteen percent reported sleep interference and 21 percent reported speech disturbance. Very few subjects reported significant annoyance, sleep interference, or speech disturbance below 50 dBA Leq.

7) Most people tried to ignore the noise when they were annoyed, regardless of noise level. However, as the levels increased, subjects who were outdoors were more likely to have moved indoors, while those indoors had a tendancy to close their windows. It was found, for example, that at 65 dBA, 39 percent of those outdoors moved indoors and approximately 69 percent of those subjects indoors closed their windows.

8) Several simple noise measures such as L_{10}, L_{50}, and Leq were equally satisfactory predictors of adverse responses to traffic noise. The Ldn was only marginally superior to Leq in terms of correlations with responses. The concept of a 10 dBA nighttime weighting was strongly supported by the results of the study.

9) Increased fluctuations in the traffic noise levels did not cause increased disturbance, but rather a slight trend towards decreased disturbance.

10) In comparison with the U.S. EPA recommended Ldn value of 55 dBA (equivalent to approximately a (24h) Leq value of 51 dBA) which is adequate to protect people from any significant impairment, Bradley suggested that 50 dBA Leq is perhaps a lower bound to the possible range of desirable noise levels, while the upper bound would be no higher than 70 dBA Leq. At this noise level over 20 percent of the population is very disturbed and on average people are moderately disturbed.

(f) During the summer of 1975 and 1976 two extensive surveys were conducted in the Hamilton and Toronto areas, by Hall and Taylor.(1)

Almost 2 000 interviews were completed at 65 sites. Sound level measurements were carried out at each site for a 24 hour period, and the data was reported in several sound level descriptors including Ldn and Leq. Figure 2.8 illustrates a summary of the results of the survey at 16 of the 65 sites wherein road traffic was the major noise source. The results reflect the percent of subjects reporting high disturbance, percent reporting any sleep interruption, and the percent reporting interruption of an activity involving speech. The study concludes that the results of high disturbance and speech interference correlate well with the measured sound levels.

(1) Refer to the reports by Hall and Taylor entitled Community Effects of Road Traffic Noise and Community Response to Noise in the Toronto-Hamilton Urban Corridors - References 34 and 35.

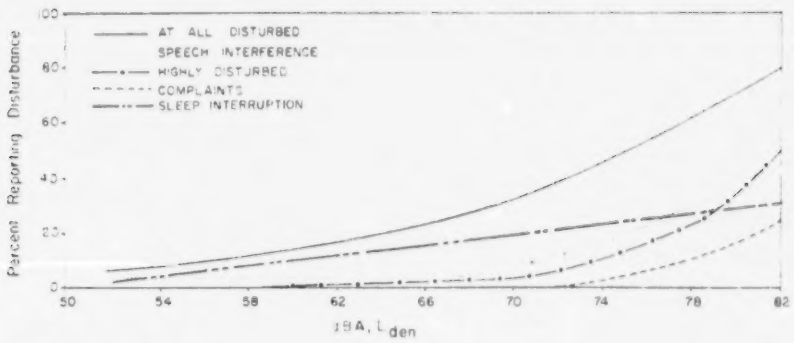


Figure 2.8
Ontario Survey Results of Reported Disturbance
(Ref: 36)

(g) During the summer of 1975 the Ontario Ministry of the Environment[1] conducted a social survey in the Toronto area. Thirty-four sites were chosen for noise monitoring and survey. Of these 17 were adjacent to train sites, nine were adjacent to arterial roads, and eight were adjacent to freeways. Approximately 10 persons were interviewed at each site using a comprehensive questionnaire. Sound level monitoring was performed for at least 24 hours at each site.

Figure 2.9 illustrates the percentage of subjects who rated neighbourhood noise disturbance for both freeways and arterial roads. Examination of this figure indicates a greater

(1) Refer to the report by Hemingway and Krammer involving the Investigation of Human Response to Road Traffic Noise - Reference 38.

disturbance by freeways. The difference may be attributed to the fact that of the sites examined, the majority of lots immediately adjacent to freeways have reversed frontage, whereas the rear yards of the majority of homes adjacent to arterial roads face away from the road. A second factor may be the difference in the sound level variability of the two sources; freeway noise being practically continuous steady noise whereas arterial noise varies over much wider limits.

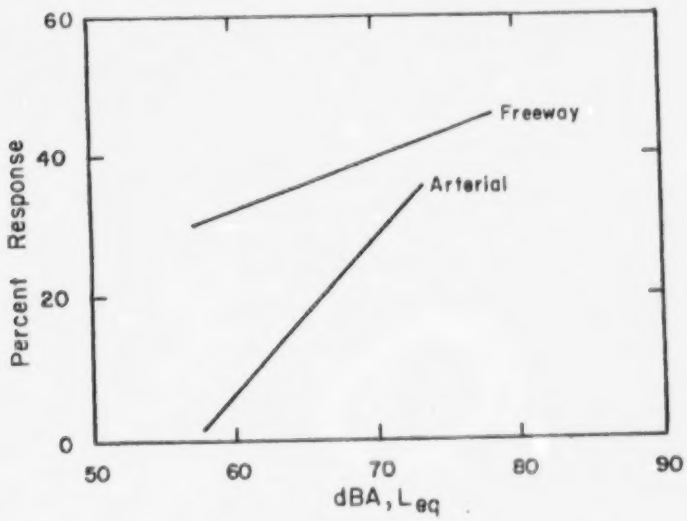


Figure 2.9
Reported Disturbance on
Arterials and Freeways
(Ref: 38)

(h) Recently, the Road and Motor Vehicle Traffic Safety Branch of Transport Canada announced the preliminary results of national surveys[1] of exposure to transportation and other noise sources which were conducted during the summer of 1978. Nearly 9 000 respondents were surveyed. The preliminary results of attitudes

(1) Refer to the Data Base of the Results of the National Household Survey of Noise Exposure prepared by Peat, Marwick, and Partners -- Reference 69.

indicate that the most frequent mentioned problem affecting neighbourhood is traffic noise. Approximately 85 percent of the subjects indicated dislike to this factor in their neighbourhood. Just under 20 percent of the sample reported sleep interruption due to various noise sources. Approximately six percent of the sample reported sleep interruption due to cars, buses, motorcycles, and trucks.

2.3.3 - Selection of Criteria Based on Social Surveys

Figures 2.10, 2.11, and 2.12 illustrate the aggregated summaries and comparisons of the results of social surveys reviewed in this study.

The findings of Canadian, European and United States experience differ to such a significant extent that it is impossible on the basis of this data to draw conclusive criteria. However, in an attempt to derive the information required, Canadian experience was separated from that of the rest. The results illustrate common trends.

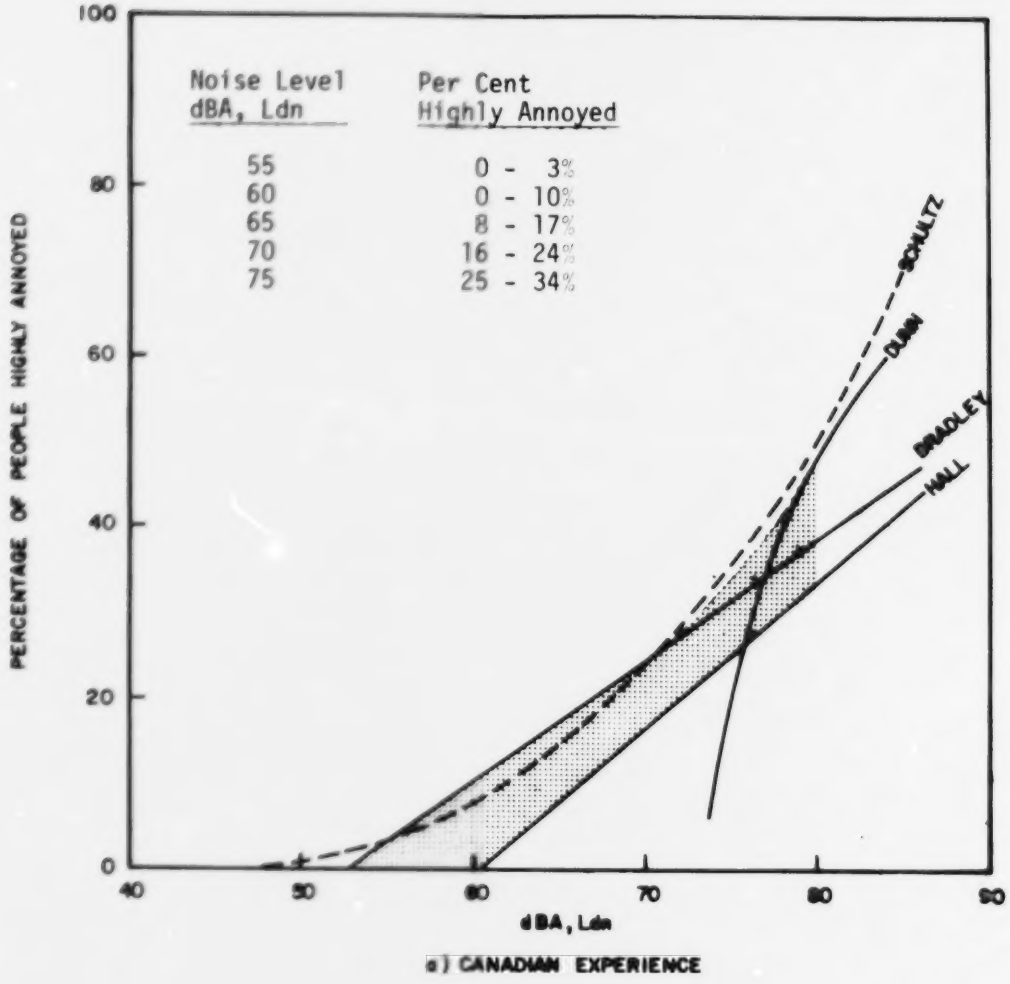
Exclusion of the European and most of the United States data appears to be a reasonable approach if one considers that

- this study deals with the Canadian scene,
- the methodologies used in each of the investigations likely differ (and unfortunately descriptions were unavailable) and so also do the definitions applied to such terms as "highly annoyed" or "highly disturbed" etc., and
- most European and U.S. data was collected many years prior to 1975 and since that time not only have measurement techniques and units of measurement changed but so also have people's awareness to noise and noise impacts.

2.3.4 - Complaints

A degree of annoyance can be gauged from questioning, as in social surveys, or from unsolicited community reaction, i.e. complaints. In

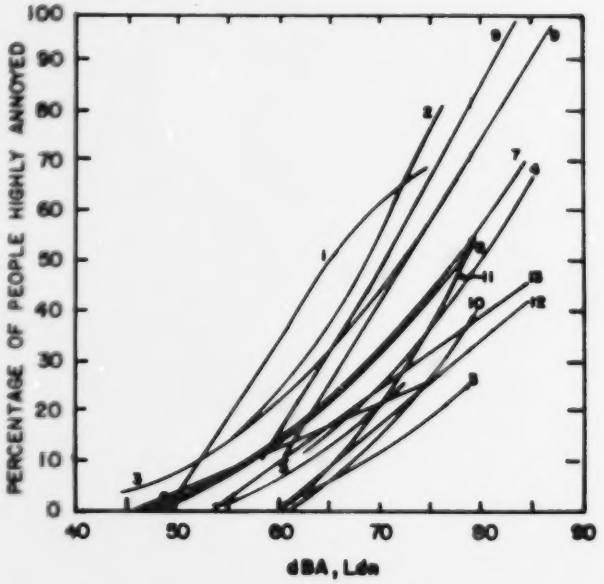
FIGURE 2:10 SUMMARY OF PER CENT HIGHLY ANNOYED



a) CANADIAN EXPERIENCE

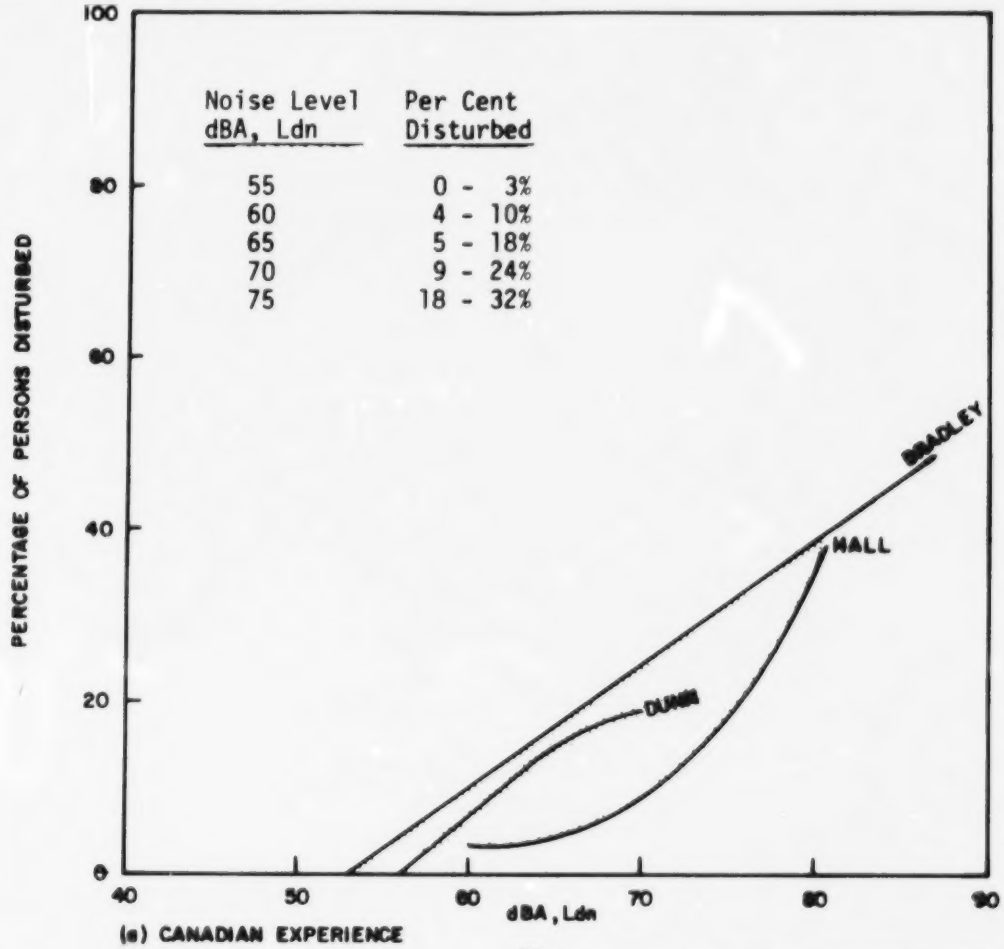
Legend

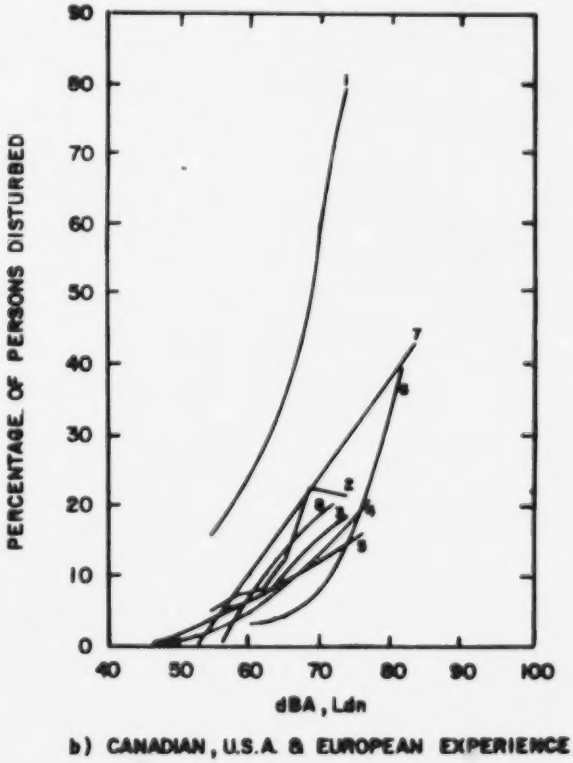
1. Vienna, 1964
2. France, 1967
3. Sweden, 1968,1975
4. Paris, 1969
5. Switzerland, 1972
6. U.S.A., 1974
7. U.K., 1972
8. Denmark, 1972
9. Vienna, 1975
10. Belguim, 1975
11. Belguim, 1975
12. Canada (Hall), 1975, 1976
13. Canada (Bradley), 1976



b) CANADIAN, U.S.A. & EUROPEAN EXPERIENCE

FIGURE 2:11 SUMMARY OF INTERFERENCE WITH SPEECH

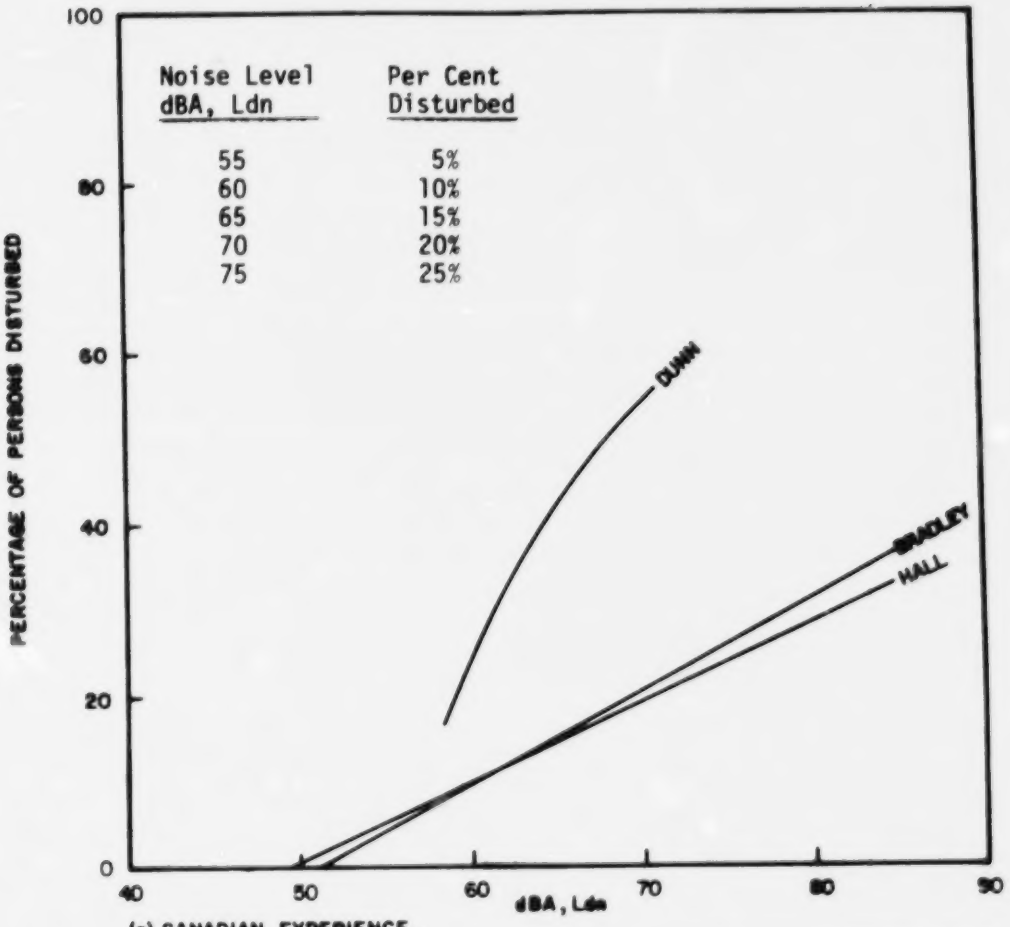




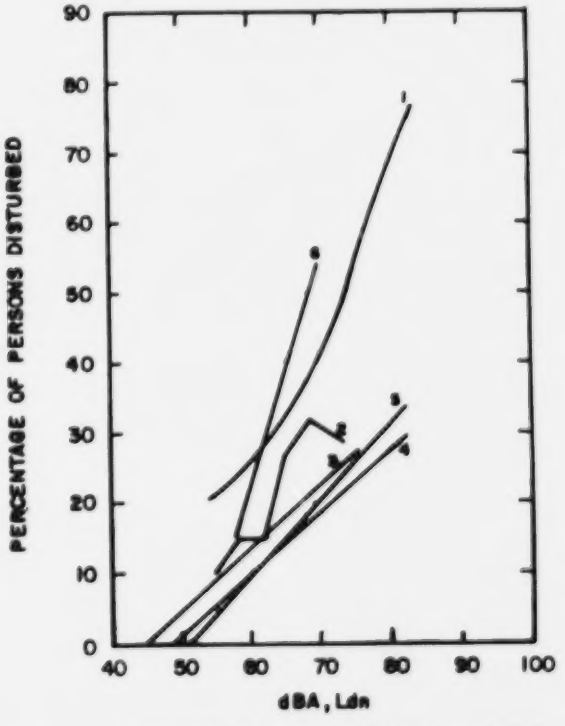
Legend

1. France, 1969
2. Switzerland, 1972
3. Switzerland, 1972
4. U.S.A., 1974
5. U.S.A., 1974
6. Canada (Hall), 1975/76
7. Canada (Bradley), 1976
8. Canada (Dunn), 1979

FIGURE 2:12 SUMMARY OF INTERFERENCE WITH SLEEP



(a) CANADIAN EXPERIENCE



b) CANADIAN, U.S.A. & EUROPEAN EXPERIENCE

Legend

1. France, 1969
2. Switzerland, 1972
3. U.S.A., 1974
4. Canada (Hall), 1975/76
5. Canada (Bradley), 1976
6. Canada (Dunn), 1979

the many studies of community response to noise, no special characteristics have been identified among those who complain. The complainants are but a small proportion of those who would express annoyance if directly questioned.

Relatively little information exists concerning the relationship between complaints and roadway noise annoyance. It may however be useful to examine some of the work in the field of airport noise. One study investigated the relationship between complaints and annoyance. The result are illustrated in figure 2.13.

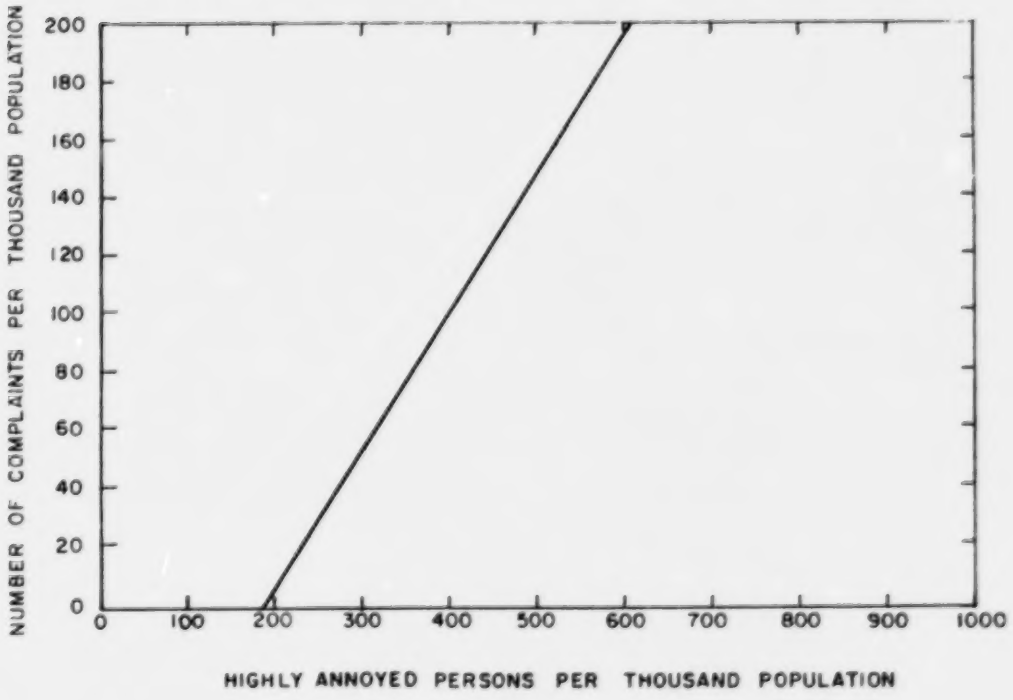


Figure 2.13
Relationship Between High Annoyance and Formal Complaints
(Ref: 71)

On the basis of the above relationship, if approximately twenty percent of the population report a high degree of annoyance when surveyed, then it is likely that one percent of the population are so sufficiently annoyed that they would submit formal complaints to authorities. From this and other studies of aircraft noise, this figure of 20 percent appears to represent a threshold level below which no complaints are expected.

Community reaction to noise is likely to be more marked in rural and suburban areas than in the urbanized and downtown sectors. Further, given levels of noise will be tolerated to a lesser extent at night or in the evening compared to working hours, and in summer as compared to winter.

A sample of complaints received from the residents of the City of Edmonton is presented in Figure 2.14.

The greatest source of complaints seem to centre around truck routes, such as Mayfield Road, and in new subdivisions where there is a large degree of construction traffic, such as in the vicinity of 119th Street. Also, the number of formal complaints has been steadily increasing, especially within the last year.

2.4 Health Effects

The following data was submitted by the City of Edmonton Health Department for consideration in the selection of a noise policy level.

The effects of traffic noise on health are diverse, involving both physiological as well as psychological responses. It is known that noise can cause temporary and permanent hearing loss, disrupt performance capability and induce undesirable behavioural effects.

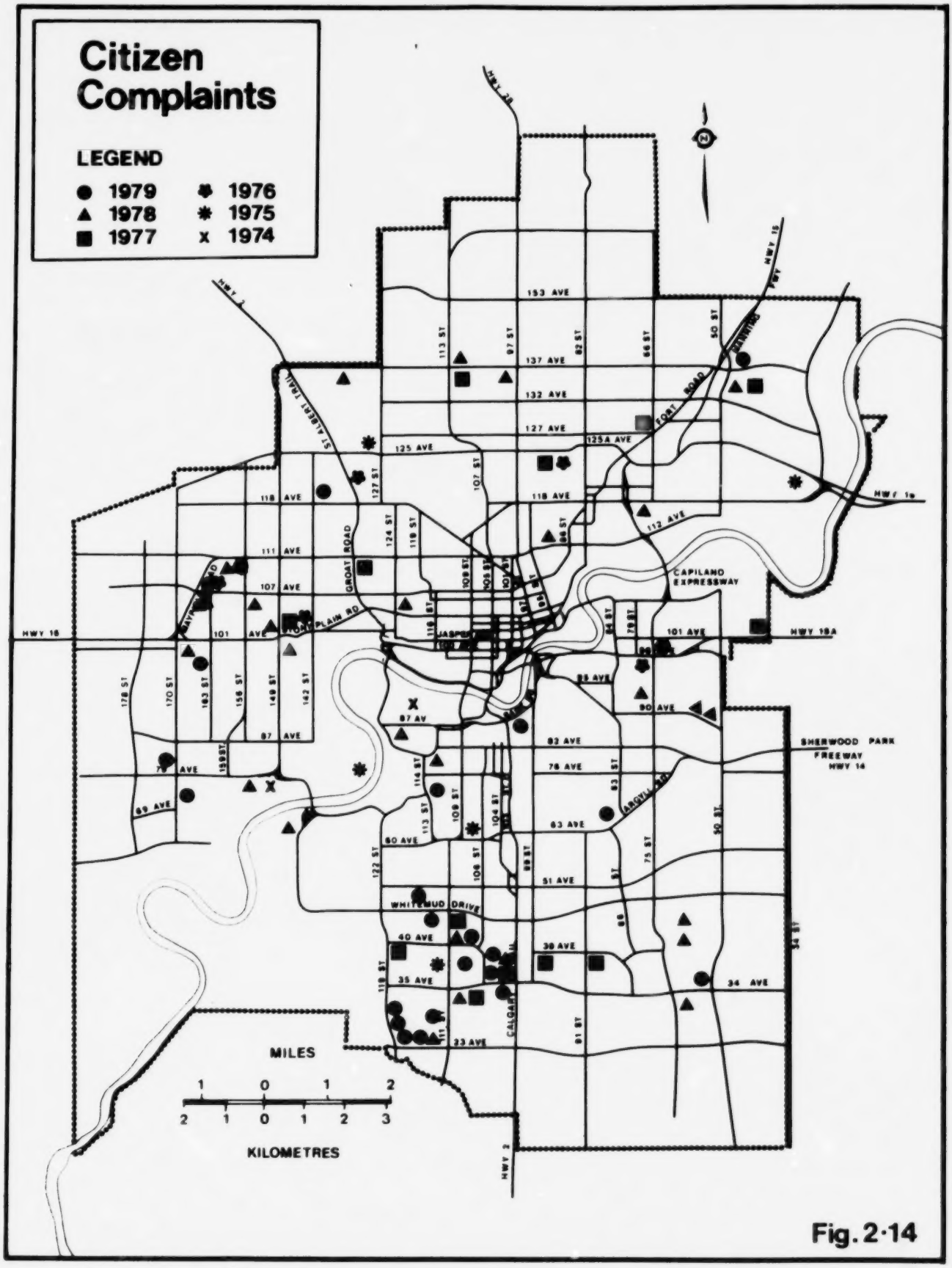

Citizen Complaints
LEGEND
1979
1978
1977
1976
1975
1974
MILES
1 0 1 2
2 1 0 1 2 3
KILOMETRES
HWY 16
HWY 16A
HWY 2
HWY 2A
HWY 15
HWY 14
153 AVE
137 AVE
132 AVE
127 AVE
125 AVE
125A AVE
118 AVE
112 AVE
111 AVE
107 AVE
101 AVE
97 AV
97 AVE
90 AVE
87 AVE
82 AVE
78 AVE
69 AVE
63 AVE
60 AVE
51 AVE
40 AVE
39 AVE
35 AVE
34 AVE
33 AVE
23 AVE
ALBERT TRAIL
GROAT ROAD
FORT ROAD
CAPILANO EXPRESSWAY
SHERWOOD PARK FREEWAY HWY 14
WHITEMUD DRIVE
ARGYLL RD
CALGARY

Fig. 2·14

2.4.1 - Hearing Loss

Hearing loss, permanent or temporary, is the most overt effect of noise and is unlikely to occur as a result of traffic noise except with prolonged exposure.

Even the most intense noise fails to damage the relatively unimportant outer ear and rarely will the eardrum be ruptured or the middle ear ossicles dislocated except by intense noise or blast. The primary site of auditory injury is the receptor organ of the inner ear, called the Organ of Corti, the integrity of which is vital to normal hearing. Excessive response to noise destroys the hair cells and other parts of the organ. The sensitivity is greater for sounds of higher frequency and regeneration does not occur.

Temporary threshold shift, that is, a change in the ability to detect sounds of particular frequencies, can occur with exposures to noise in excess of 60 to 80 dBA for periods ranging from 8 to 24 hours. People differ in their vulnerability to noises of different pitches. For instance, women are less sensitive to low frequencies and more sensitive to high frequencies. Recovery is rapid when the threshold shift in noise intensity is small and duration of exposure short.

In assessing the significance of permanent hearing damage, the thresholds for tones in the region most important for speech are negligible, even though they may be important in some occupations.

The U.S. Environmental Protection Agency(1) has concluded that permanent hearing damage can occur after prolonged exposure to noise levels in excess of 70 dBA, Leq. This conclusion is subject to criticism. For example, Kryter(2) has suggested that potential damage may occur at noise levels above 55 dBA.

(1) From the report on Levels of Environmental Noise to Protect Public Health and Welfare prepared by the U.S. Environmental Protection Agency -- Reference 90.

(2) Refer to Kryter, K.D., Impairment to Hearing From Exposure To Noise, Journal of Acoustical Society of America, 1973.

These noise levels can be produced by traffic noise, although more likely sources of these levels of noise are vocations involving heavy construction or loud (rock) music.

2.4.2 - Effects on Performance Capabilities

While changes in performance do occur in noisy environments, they vary widely among different test subjects.

Steady noises do not appear to interfere with human performance until the levels reach approximately 90 dBA. However, irregular bursts below this level and of higher frequencies do have an effect. Noise reduces the accuracy of work more than the quantity of work. Complex tasks are more likely to be adversely affected than simple tasks. In some circumstances individuals of high intelligence do less well while low intelligence subjects may experience improved performance.

Physical changes detectable in the presence of noise indicate that noise is a source of stress. Common responses to noise include increased blood pressure levels and vaso-constriction of the fingertips and temples. Dunn(1) reports that "noise itself has been shown to be a more serious stressor than arterial incision, moderate adrenaline injection, or hemorrhage in laboratory study".

Other non-auditory effects on health which have been reported include physiological disturbances involving the cardiovascular and nervous systems. Road traffic noise can lead to distinct temporary changes in blood levels of sugar, uric acid, total lipids, cholesterol, and triglycerides, the effect becoming more marked with louder noise of longer duration. The significance of these biochemical changes has not been established.

(1) From a Summary Report of the Calgary Noise Survey prepared by Dunn for the Alberta Environment -- Reference 1.

2.4.3 - Behavioural Impacts

Nausea, headaches, instability, argumentativeness, sexual impotency, changes in general mood, anxiety and other effects have been associated with exposure to noise but all are difficult to assess.

Studies indicate that persons in noisy neighbourhoods have more admissions to mental hospitals, more consultations for emotional disturbances, and a greater incidence of drug treatment for personality disorders.(1) Again, however, it is difficult to dissociate socio-economic factors from health effects, since lower income groups tend to locate in noisier neighbourhoods and they are also the group most susceptible to psychological disturbance.

Psychological effects of noise are definite. Mental disorders can be initiated or aggravated by noise but the cause-effect relationship is clouded by a variety of social and environmental factors influencing the human response to noise.

Non-auditory effects of noise on health undoubtedly occur but are difficult to equate with precise levels of sound. It is not yet possible to correlate the cardiovascular effects of noise with susceptibility towards disease. Nor are the long term effects of noise on man well defined. Research in this area is continuing and it is anticipated that the results will shed light on noise-tolerant and noise-sensitive personalities.

(1) Refer to the Medical Effects of Environmental Noise on Humans by Arlin and Ohstram -- Reference 7, and the report on the Health Effects of Noise Exposure by Krichagin -- Reference 41.

2.4.4 - Preliminary Recommendations

The survey conducted by the City of Edmonton Health Department is of greater depth than the rest of the material assembled for Stage I by the consultant. Due to the extent of the data collected, the Health Department is prepared to submit the following preliminary noise policy level recommendation. The consultant's recommendations will be forthcoming at the end of Stage II of the study.

At this time, the Health Department recommends a preliminary policy level of 55 dBA, Ldn in residential neighbourhoods. Although primarily designed to permit speech communications and minimize annoyance and public complaints, this level is suggested by the U.S. Environmental Protection Agency as a requisite for the protection of public health and welfare with an adequate margin of safety.

It is only below this level that minor health disturbance due to noise will be assured. As the level of noise in residential neighbourhoods increases from 55 dBA, Ldn increasing public physiological and psychological disruption is seen to occur.

2.5 Economic Impacts

In determining the "worth" of a noise abatement program it is necessary to establish some ideas of costs to be expended and the benefits to be accrued. Establishing the cost required to achieve a given noise standard is relatively simple. However, defining in economic terms, the benefits to be accrued or the economic losses associated with inaction is extremely complex and difficult.

Economic models that are capable of accurately quantifying social costs of noise and economic impacts of noise on property are not available. Such models are currently being investigated and some information has been published. However the information is limited and is considered insufficient for use as criteria for decision making, particularly for setting noise standards.

The following sections outline the methods for assessing the economic impacts of noise which are currently under investigation, the related difficulties and limitations as well as the numerous parameters which must be considered.

2.5.1 - Indirect Market Indicators

Price in the traditional sense is fixed in the market place. However, there is no market for noise. Therefore, it is necessary to search for indirect indicators by which to estimate the price of noise.

One indirect market indicator that has been suggested is medical expenses[1] attributed to noise. Such an indicator may not be totally reliable since, despite medication which will relieve fatigue, annoyance and stress, the individual's state of well being may not be fully restored.

1) Refer to a report on Road Traffic Noise by Alexander -- Reference 3.

Another indirect market indicator that has been suggested is the money an individual is willing to expend on noise abatement such as an outdoor barrier or double glazing. Once again this indicator may not be totally reliable. The motivation for installing double glazing may be related to other factors, such as increasing the capital value of the property or a desire to improve thermal insulation.

The fact that questions about money do not actually require the respondents to produce or expend such funds, allows the respondent to suggest any dollar figure he chooses. A study conducted in Troy, Michigan[1] suggests that homeowners are willing to pay for noise reduction. In that particular instance the homeowners themselves financed the construction of an earth berm to reduce highway noise through special assessment levied by the Municipal Tax Assessment Office. In a social survey, the homeowners reported a willingness to pay between $145 and $235 per dBA attenuation and for other benefits associated with the berm.

Since relatively little information exists with respect to quantification of social costs related to roadway noise, it is useful to examine some of the work in the field of airport noise. Some of the techniques developed in this area may be of use in future evaluation of roadway noise.

Three methods which have been used to determine the economic impact of airport noise in the United States include:[2]

(a) "Noise" Easements

In an attempt to determine the magnitude of a given noise problem, and compensation for reduced land values due to aircraft noise, the U.S. EPA examined the costs to obtain easements around all major airports. The costs to obtain these easements were estimated to be in the order of 6 to 27.75 billion in 1978.

(1) From a report by Van Buseck on the Measurement of Reduced Taffic Noise Annoyance Obtained With An Earth Berm - Appendix B.1.

(2) Refer to the study of Transportation Noise Impacts and Analysis Techniques by Argon National Laboratory -- Reference 6.

(b) Litigation

A second indicator of the economic impact of airport noise was litigation costs. A total cost of approximately $7.5 billion was estimated as the likely outcome of damage suits for inverse condemnation, personal injury and property damage.

(c) Insulation Costs

A third alternative involved the estimation of insulating either the aircraft and or the homes in all areas exposed to a level in excess of 30 NEF. The cost of insulating some four million households was estimated at between $10.7 and $35.7 billion. In addition, an engine retrofit program for all jet aircraft was estimated to cost between $3.8 and $5.7 billion.

An alternative method for estimating the cost of noise involves the estimation of the demand for noise abatement. The Roskill Commission on the third London Airport developed such a model via a survey of adjacent residents. Survey questions pertained to the price people would be prepared to pay to eliminate excess noise.

Yet another approach involved the concept of an "endurance cost" and a "dislocation cost". The former cost was estimated by asking people how much they would accept in payment for the "inconvenience" of high noise levels. The concept of "dislocation cost" involved asking respondents the amount of money they would be prepared to accept to move to another residence.

2.5.2 - Impact on Property Values

A number of researchers have attempted to isolate the effect that noise might have on property values with varying results:

The Rand Corporation, in the report entitled Economics of Expressway Noise Pollution Abatement developed a model to reflect the impact of

noise on property values. Their results indicated that there was a damage in dollar, or depreciation associated with the market value of the house resulting from higher noise levels.

A recent report by Breston,(1) arrived at the conclusion that a reduction of $312 per decibel could be attributed to noise for homes located in close proximity to expressways. Breston determined that a lower, yet significant figure of $254 per decibel, could be attributed to homes located along arterials.

Breston's work is considered an improvement on earlier studies and one of the most reliable. However limitations governing her results include;

- limited consideration of other parameters which establish house prices,
- limited considerations of other roadway annoyances including fumes, dust and dirt, lack of privacy etc.,
- limited consideration of incomes of homeowners.

2.5.3 - Assessment and Property Appreciation

Assessment information received through discussion with the City of Edmonton Assessment Department and via telephone interviews would suggest that dwellings located immediately adjacent to major roads are assessed at a slightly lower value. The magnitude of the difference varies from about five to fifteen percent. None of the Municipalities contacted could isolate the noise component from others such as dust and debris, privacy intrusion etc. Although statistics on economic loss can be developed, significant information on cost recovery following construction of a noise barrier or after introduction of noise abatement is not available. One case study (Appendix B.1) reports a perceived appreciation of house resale value, by residents, due to the construction of an earth berm to be approximately $650 per dwelling. House prices ranged between $60 000 to $70 000.

(1) Refer to a report on the Impact of Road Traffic Noise on Property Values by B.E. Breston -- Reference 14.

2.5.4 - Limitations of Economic Impact Assessment

The Economic Impact of noise has yet to be dealt with in a definitive manner. Some approaches have been outlined in this section. These indicate that:

- Noise may depreciate the value of property, and
- There may be a dollar value associated with noise abatement that can reflect "benefit" in economic terms.

Studies of the economic costs of noise have to date had the following limitations:

a) They have to a large extent failed to take into account other negative economic factors. These may include high noise levels which create a poor learning situation for students, the interruption of quiet in parks and recreational areas which may have been disrupted by high noise levels and an overall deterioration of the outdoor environment which may affect such activities as outdoor concerts. It is difficult to assess the economic losses which may be attributed to the loss of such activities.

b) Many factors influence the housing market and it is difficult to isolate the effects of noise. People frequently endure noise because they have no other alternatives and this is probably the main reason why housing market models fail to evaluate the social cost of noise.

c) The influence of noise on property values does not likely reflect the social losses as people are likely not to consider the long term effects of noise on health and welfare.

d) The average person is unable to define monetary benefit resulting from noise abatement.

e) Much of the work involving the determination of the social costs of noise relies on surveys of people which involve questions. The fact that questions about money do not actually require the respondent to produce money, allows the respondent to "suggest" any figure he chooses.

f) Factors involving differing socio-economic classes make it difficult to define the social cost of noise. Specifically, an individual with a high socio-economic class may have various options at his disposal and may become more aware of the environment in which he is purchasing a home whereas an individual within a lower class may not have as many options and factors concerning his environment are likely of lesser significance.

g) Social surveys to date have not examined the "option loss" of individuals living outside the noisy area who may wish to live within that area if it were not for the noise.

2.6 Summary

To varying degrees, persons residing adjacent to arterial roads are all subject to social-environmental, health, and economic related traffic noise impacts. Social and environmental noise impacts may include interference with speech and communications, interference with sleep and interference with recreational activities generally of a passive nature.

Health related impacts may involve both physiological as well as psychological responses causing either temporary or permanent hearing loss, reduced performance capability or undesirable behavioural effects.

Economic related impacts may include decreased property values, costs associated with noise attentuation or perhaps even medical expenses resulting from injurious health affects.

Presently, little data is available on the effects of traffic noise on health or economic related impacts. There has, however, been surveys that have provided information on the social-environmental effects of traffic-related noise. Also, the relationship between the number of complaints and the number of people highly annoyed at certain noise levels has been determined from a study on the effects of airport noise. These impacts are illustrated in Table 2.1.

Table 2.1
Social-Environmental Traffic Noise Impacts

Noise Level (dBA, Ldn)	Percent of Population Likely to Report			
	Speech Interference	Sleep Interference	High Annoyance	Formal Complaints
55	0-3	5	0-3	0
60	4-10	10	0-10	0
65	5-18	15	8-17	0
70	9-24	20	16-24	0-2
75	18-32	25	25-34	3-7

Further details on the impact of traffic noise is presented in Sections 2.1 to 2.5.

3. Existing Noise Standards

3. EXISTING NOISE STANDARDS

3.1 International Levels

The control of noise in residential areas has become a major world-wide concern within the last few years. However, difficulty in comparing the extent to which various countries have taken to regulate noise arises when considering the different methods or practices each country employs.

First, many of the acceptable noise standards vary with respect to time of day, but the hours assigned to these time periods differ from country to country. For instance, "day" is defined as 6 a.m. to 11 p.m. in Sweden, 7 a.m. to 7 p.m. in the Netherlands, and 6 a.m. to 10 p.m. in Switzerland. Similar discrepancies occur in the division of hours for "night", while other countries, such as Japan, have separate specification for "morning" and "evening."

Second, the limits expressed in various countries have many designations. Although the units within which noise is measured are fairly universal (dBA), the way in which the limits are expressed differ. Table 3.1, illustrates the units which several countries utilize.

Table 3.1

Country	Limit Expression
Sweden	DAY Leq (6 a.m. - 11 p.m.) NIGHT Leq (11 p.m. - 6 a.m.)
Netherlands	DAY Leq (7 a.m. - 7 p.m.) NIGHT Leq (11 p.m. - 7 p.m.)
Japan	DAY L_{50} EVENING L_{50} NIGHT L_{50}

Table 3.1
(continued)

Country	Limit Expression
Switzerland	DAY L_{50} (6 a.m. - 10 p.m.) NIGHT L_{50} (10 p.m. - 6 a.m.)
France	L_{50}
Denmark	Leq (24 hours)
United Kingdom	L_{10} (18 hours)

In addition to the various division of hours and the different units within which the limits are expressed, the degree to which the standards or limits are enforced also differ. Switzerland, Sweden, France, the Netherlands, and the United Kingdom for instance, set criteria or limits which, by law, must not be exceeded. Other countries, including Denmark, and Japan, set guidelines which recommend satisfactory or acceptable noise levels. These are strictly desirable goals of the government.

Noise regulations and standards are becoming increasingly common in statutes which deal with environmental and health issues. Programs have been established with noise abatement as the prime objective. In Sweden, the Building Statute of 1957, the Health Service Statute of 1958 and the Environmental Protection Act of 1969 include provisions dealing with the regulation of noise. Similar steps have been taken by the Netherlands (Noise Abatement Bill, 1975), Japan (Environmental Quality Standards, 1971), and Switzerland (Swiss Federal Constitution concerning Environmental Protection, 1971) to regulate road traffic noise levels in residential areas. Similar acts and statutes dealing with noise have also been established in Denmark, the United Kingdom and France.

The objective of these acts and statutes is to limit or reduce the noise levels, especially in residential areas during various times of the day.

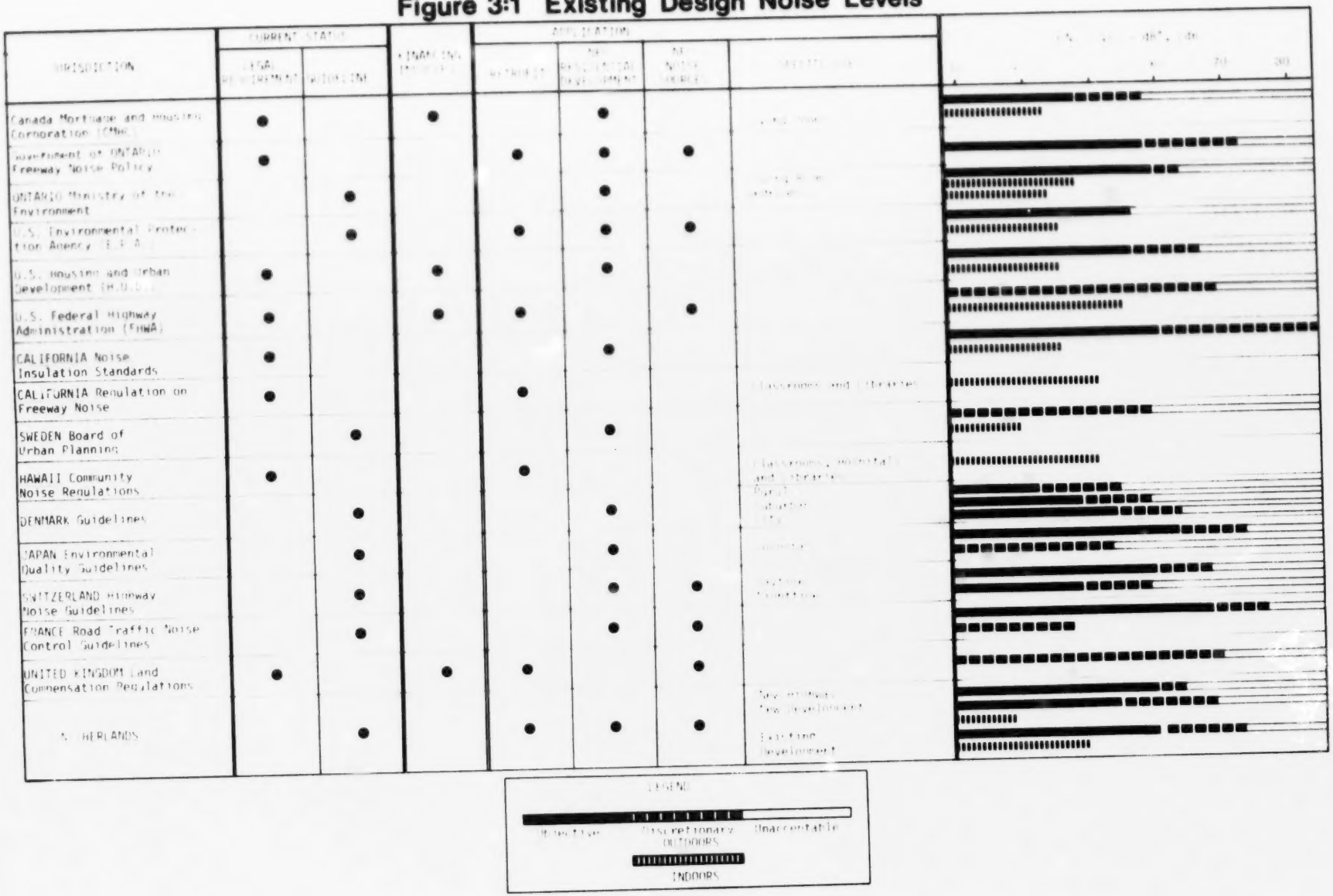
Figure 3.1 illustrates the existing design noise levels for several countries around the world, some of which are legal requirements and others are guidelines or policies unenforceable by law, and indicates the location and time where these levels are effective. For ease of comparison, all design noise levels have been converted to a single descriptor, the energy equivalent day-night sound level, Ldn.

3.2 Levels Established Within the United States

Within the last few years in the United States, Federal Agencies have set general policies, standards, and guidelines for the protection of the health and welfare of the general population against excessive noise. The United States Environmental Protection Agency (E.P.A.) has established an objective level of 55 dBA Ldn as the basis for regulations to be set by state and local governments to ensure a noise level with an adequate margin of safety. The United States Department of Housing and Urban Development (HUD) has also set an objective level of 55 dBA Ldn to provide a suitable living environment within residential developments. Noise levels up to 65 dBA Ldn are also acceptable, but measures must be taken to attenuate noise levels greater than 65 dBA Ldn. These, too, are guidelines set by the Federal Government whose specifications are not intended to be strictly enforced, but to provide a basis with which local or state governments can set their standards.

Another federal agency involved in noise abatement in residential areas is The Federal Highway Administration (FHWA). This agency sets policies and procedures for noise studies and noise abatement measures for use in the planning and design of highways. Projects include proposed federal or federal-aid highway construction or

Figure 3:1 Existing Design Noise Levels



reconstruction, as well as those which involve noise abatement on an existing highway which does not include construction or reconstruction of a highway section. The attenuation of traffic noise from existing highways by utilizing retrofit is not a mandatory requirement, but an option of the highway agency. For residential areas, interior noise levels specified by the FHWA are 52 dBA Leq or 55 dBA L_{10}.

State agencies generally provide more stringent laws and standards than those suggested by the federal agencies. The State of California, in particular, has passed a comprehensive set of state laws, standards, and procedures for the control of noise. Included, is the California Noise Planning and Land Use Act (1971) which requires that the noise levels associated with highways and freeways be illustrated quantitatively and numerically in order to show where noise barriers are needed most. The California Streets and Highways Code (Section 216) states that noise abatement is necessary when noise levels in classrooms exceed 50 dBA Ldn. Also, the California Noise Insulation Standards (California Administrative Code, Title 25, Chapter 1, 1974) has established a noise level of 60 dBA Ldn, after which insulation of hotels, motels, apartments and dwellings other than detached single-family dwellings, is mandatory.

In Hawaii, the Oahu Community Noise Control Regulations were established to prevent and control excessive noise received inside any school classroom, library, hospital, or rest home. Measures to attenuate the noise must be provided if the level exceeds 50 dBA Ldn.

3.3 Levels Established Within Canada

Federally, the establishment of standards on road noise as they affect the financing of new housing in Canada has been undertaken by the Canada Mortgage and Housing Corporation (CMHC) in 1977. These standards deal specifically with new residential development which may be adversely affected by noise from roads and railways. They are mainly receiver-oriented noise level standards, and do not address noise due to the development of new roadways, nor retrofit projects.

The maximum acceptable levels of road traffic noise in new residential dwellings are dependent on the location within the dwelling. This value is 35 dBA Leq for bedrooms, 40 dBA Leq for living and dining rooms, 45 dBA Leq for kitchens and bathrooms, and 55 dBA Leq for outdoor recreation areas.

Provincially, traffic noise control programs exist at various levels of government. In Ontario, the Ministry of the Environment has, since 1974, developed a broad source-oriented and receiver-oriented environmental noise control program that covers regulation development, standard setting, and enforcement of noise levels. The Noise Pollution Control Section, Pollution Control Branch of the Ontario Ministry of the Environment is responsible for investigating sources of sound and vibration, evaluating their impact on the environment, and developing plans, policies, and programs for their control within a Federal/Provincial/Municipal framework. In setting acceptable sound level objectives, the Noise Pollution Control Section adopted interim criteria in 1974 based on the results of the study prepared for the United States Department of Housing and Urban Development (HUD). These limits are currently in use by the Ministry of the Environment as guidelines for evaluation of new residential and noise sensitive developments. The objective level has been established as 55 dBA Leq (24 hours) in outdoor recreational areas of residential developments. Concerning noise due to freeways, the Ministry of Transportation and Communications (MTC), Ministry of Housing, and the Ministry of the Environment announced a joint policy requiring noise barriers to be provided by MTC for new construction work on major freeways through existing residential areas. It was also stated that developers of new residential units near freeways would have to include similar measures to reduce noise impact. The details of the policy were announced in April 1979. The provincial government also prepared an all-encompassing policy aimed at control of freeway noise at the source as well as at the receiver, in addition to retrofit programs aimed at controlling existing freeway noise with the construction of noise barriers on a priority basis.

On the municipal level, bylaws have been designed to prohibit, eliminate, and abate noise within the municipality, prohibiting persons from permitting or causing noise greater than a specified level. In the City of Edmonton, Bylaw Number 4110 establishes maximum acceptable noise levels within residential areas of 65 dBA during the day and 50 dBA at night. This bylaw also limits the amount of noise that may be emitted from vehicles, as measured near the source. Motorcycles, automobiles, and light trucks may not produce noise levels in excess of 83 dBA, as measured five metres from the vehicle. For heavy-trucks, this restriction is 90 dBA, and 92 dBA for diesel powered motor vehicles.

Alternatively, the City of Calgary is reviewing a proposal that a noise bylaw not be established within existing residential areas.

3.4 Summary

The control of noise levels in residential areas has only recently been given serious consideration by all levels of government throughout the world. An increasing number of federal governments have taken steps to set guidelines or criteria to limit the amount of noise allowed in residential developments. Provincial and state governments have generally regulated noise levels by implementing more stringent laws and standards detailing acceptable or objective noise ranges. Presently, few municipal governments have initiated programs or policies dealing with noise standards.

As illustrated in Figure 3.1 there is considerable variation among the standards. Most jurisdictions do not administer a comprehensive noise control program. Those who do include the Province of Ontario and the State of California. Many jurisdictions do not possess direct legal means for the enforcement of noise controls and instead rely upon general provisions contained within other acts or guidelines. For example, the Ontario Ministry of the Environment and Sweden both rely upon general provisions set out under planning guidelines.

Whereas most jurisdictions address general land uses, some jurisdictions emphasize the need for noise control of special uses. For example, both the State of California and the State of Hawaii require the control of excess noise within classrooms and libraries. Financing of noise attenuation is generally controlled by authorities at the Federal or State level, eg., CMHC and FHWA. The United Kingdom is the only jurisdiction identified which provides compensation due to traffic noise and this compensation is provided only after the applicant satisfies very stringent conditions.

In general, the objective outdoor noise levels set by the majority of jurisdictions range between 55 and 60 dBA, Ldn and most jurisdictions identify levels in excess of 65 dBA, Ldn to be unacceptable. Many jurisdictions also provide standards for indoor noise control. Of those surveyed, the majority identify acceptable levels to be those not exceeding 45 to 50 dBA, Ldn.

4. Review of Noise Barrier Experience

4. REVIEW OF NOISE BARRIER EXPERIENCE

4.1 Methods of Survey

Information concerning noise barrier retrofit programs, barrier costs and financing, benefits and disadvantages was collected through an extensive literature search, mailed questionnaires and selected telephone interviews.

The literature search was carried out by the consultant and involved a review of over 100 noise related documents prepared by consultants, agencies, and various levels of government throughout the world. These references are listed in Appendix C of this report.

The questionnaire was developed and distributed by the City of Edmonton, to 200 agencies in Canada and the United States. Of these, 61 were completed and returned. However, only eight responses reported any experience with noise policies or noise barrier programs. These eight responses are identified as the City of Sacremento California and the states of Arizona, Florida, Illinois, Iowa, New York, Pennsylvania and Washington.

Twenty-four telephone interviews were undertaken by the consultant, to obtain supplementary information concerning noise barrier experience at various government levels in Canada and the United States. The agencies contacted are identified as follows:

- Canada

  - Mortgage and Housing
  - Ontario Ministry of the Environment
  - Ontario Ministry of Transportation and Communication
  - Burnaby, British Columbia
  - Mississauga, Ontario
  - Region of Waterloo, Ontario
  - Toronto, Ontario

- United States

  - Federal Highway Administration
  - State of California
  - State of Colorado
  - State of Connecticut
  - State of Maryland
  - State of Michigan
  - State of Minnesota
  - State of New Jersey
  - Ceritos, California
  - Denver, Colorado
  - Long Beach California
  - Minneapolis, Minnesota
  - Ontario, California
  - Pheonix, Arizona
  - Warren, Michigan
  - Washington, D.C.
  - West Hartford, Connecticut

The findings of the telephone interviews and mailback questionnaires were used to supplement and confirm the information gathered from the literature search.

Results from the surveys indicate that existing noise barrier programs are generally under the jurisdiction of a state or provincial agency which may or may not be acting on behalf of a federal authority. Most barrier programs apply only to highways under federal, state or provincial jurisdiction.

Few municipalities have implemented barrier retrofit programs. Ceritos, California with a budget of seven million dollars to provide 7.3 kilometres (4.5 miles) of barrier is the only municipality contacted with a program of significant magnitude. In Canada, the City of Edmonton and to a lesser extent the City of Mississauga are involved in studies dealing with the implementation of barrier retrofit programs on arterial roads.

4.2 Reported Barrier Characteristics

The design and contruction of an effective and economical noise barrier requires a detailed examination and evaluation of the site specific noise levels, topography, and available options.

4.2.1 - Barrier Criteria

To be effective, a barrier must be high enough to limit the amount of sound that can pass from the source to the noise sensitive area, or receptor. This includes the sound travelling directly from the source, sound reflected off opposing barriers and sound diffracted off the top edge of the barrier. Difficulty in determining the design height of the barrier arises when considering the various heights of sources and receptors. The height of source ranges from the contact point between vehicle tires and pavement to a height of about ten feet at the top of a diesel exhaust stack. As a result, the degree and type of truck traffic plays an important role in determining the height of the barrier. The noise sensitive area is generally taken as the height of first storey windows or 1.5 to 1.8 metres (five to six feet) above ground level for outside receptors. Location of second storey windows and balconies facing major roads should be investigated on a case-by-case basis but it is usually unreasonable to choose barrier heights based on these latter standards. In general, noise barriers have been found to be an effective means of reducing noise at the ground storey and to be economical if barrier heights are limited to six metres maximum.

The length of a noise barrier extending parallel to a major road must be determined in order to adequately protect properties near the edge of a residential development. While nearby receptors will usually govern barrier design heights, more distant receptors may govern the design length of a barrier. Unless this length is sufficient, noise may be transmitted from sections of roadway beyond the barrier or sound waves may diffract from the source around the ends of the barrier. The length of barrier extending past the edges of a

development should be about two to four times the setback of homes behind a barrier in order to protect the residences from flanking noise. The length of this extension can be reduced slightly if the barrier is "wrapped around" the end of the residential development, although considerably more right-of-way would be required to accommodate this feature. The total length of barrier constructed is dependent on the specific situation under investigation, and the characteristics of the residential development and highway.

Barriers may range from a few hundred metres, such as the 540 metre combined earth berm and wall barrier in South Minneapolis, Minnesota, to several kilometres, such as the four kilometre steel barrier along Highway 401 in Toronto, Ontario.

The number and size of gaps, cracks, or other leaks in noise barriers must be minimized to prevent the transmission of sound waves through the barrier. If the area of such openings is within two to three percent of the surface area of the barrier, there is little detriment to the perceived noise level. A greater percentage of openings is allowable if the height of the barrier is increased to compensate for the greater sound transmission that would have resulted. However, these cracks may detract from the appearance of the barrier and highly visible openings would raise questions about the acoustical effectiveness and quality of construction of the barrier. Attempts must therefore be made to eliminate such openings by avoiding materials and construction methods conducive to those problems, such as wood that contain knots or have a tendancy to shrink.

The placement of a barrier between the noise source and receptor, is important to determine the degree of sound attenuation. The ideal location is as close to the roadway as practical in order to achieve the greatest benefits for the most people behind the barrier. Also, at this location, the amount of sound able to diffract over the top of the barrier to the receptor is minimized. A secondary choice would be to locate the barrier as close to the receptor as possible, since the angle through which the sound waves must diffract to reach the

receptor is again maximized. Intermediate positions provide less effectual noise abatement. In many instances, selection of the best site must be deferred to other more important criteria and in such instances barriers are constructed on the property line.

4.2.2 - Barrier Designs

In addition to the physical dimensions and location of a noise barrier, the type of material and associated construction methods must be considered before an adequate design can be implemented.

Regardless of the type of material used, the thickness of barriers must be great enough to prevent sound from transmitting through that particular material. This property is usually stated in terms of density. Ten kilograms per square metre (two pounds per square foot) is the minimum density required to provide adequate noise attenuation (for timber the minimum density should be 20 kilograms per square metre or four pounds per square foot in order to withstand wind loads and minimize problems due to settlement). Table 4.1 illustrates the surface densities of several common barrier materials.

Timber is a popular material used since it is structurally efficient, simple to erect, and relatively inexpensive. Also, it is natural and aesthetically pleasing, and can be easily dismantled if changes in alignment are necessary. However, wood is susceptible to shrinkage and therefore requires periodic treatment and maintenance (such as caulking to repair cracks and gaps).

Table 4.1
Surface Densities of Common Barrier Materials(1)

Material		kg/m²	lb/ft2
Steel		195	40
Aluminum		68	14
Lead		269	55
Wood,	seasoned softwood	12	2.5
	common hardwood	20	4.0
	particle board	15	3.0
	blockboard	15	3.0
	dense hardboard	24	5.0
	plywood	12	2.5
Concrete,	dense, reinforced	59	12
	lightweight, typical	29	6
Brick, common		49	10
Glass		63	13
Stone		49-73	10-15
Plastics		24-44	5-9

The use of precast concrete panels for noise barriers is less widespread than wood but provides an effective alternative. It presents a high quality appearance, although sometimes does not blend with the surroundings, and requires little or no maintenance aside from the repair of occasional cracks. The use of wide panels is efficient since they are simple to fabricate, mass produce, ship, and erect at moderate cost. Curves and changes in alignment and grade can be easily handled and dismantling can be accomplished without much trouble. An example of a barrier constructed from precast concrete panels which has been well received by residents is in the Municipality of Metro Toronto, along the Don Valley Parkway.

(1) Densities based on an assumed thickness of 2.54 cm (one inch).

The use of metal panels for noise barriers is a relatively recent development. A major disadvantage is that the metal walls tend to impart an industrial appearance to the neighbourhood and thus, generate unfavourable public reaction. However, the risk of external rust to steel panels has been virtually eliminated with the use of an acrylic finish coating, and aluminum panels can be colour anodized to enhance its appearance.

Earth berms or mounds used as noise barriers can be implemented only if a large amount of land is available to accommodate side slopes which are generally recommended to have ratios of approximately three to one. The advantage of these earth berms is that they can utilize waste grading material and maintain a natural, pleasant landscape. In many cases, berms are built in conjunction with other forms of barrier wall, such as wood or concrete, which are located on top of the berm thus increasing the barrier height and reducing overall land requirements.

Presently, the use of specially produced materials for noise barriers is becoming popular. For instance, a sound absorptive panel made of chemically mineralized and neutralized organic softwood shavings, bonded together under pressure with portland cement and with a concrete backing is commonly used. Installation is simple and fast, and effective sound attenuation is provided.

Table 4.2 illustrates the physical characteristics of several common noise barrier materials.

As with other structures, noise barrier walls must be constructed to withstand the external loads. In the case where posts are used, the foundation must be sufficiently deep to support the wall against wind loads and also prevent settlements which may cause cracks, gaps, or openings in panels. In order to determine the depth to which the posts must be embedded, a soil investigation should be undertaken to determine its characteristics.

Table 4.2
Material Characteristics For
Highway Noise Barriers

RATING: E = EXCELENT, G = GOOD, P = POOR

DESCRIPTION OF MATERIAL	Physical Durability	Sound Absorption	Flame & Smoke Hazard	Cleaning & Maintenance	Aesthetics & Appearance
Steel Single-Leaf Panels Painted & Rust-Proofed	G	P	E	E	G
Extruded Aluminum Profiles (DAF Aluminum Acoustic Barrier)	E	P	E	E	G-E
Composite Steel Panels (I.A.C. Noiseshield Barrier)	G	G	E	G	G
Plywood Walls	P	P	P	P	P-G
Timber Walls	G	P	P	P	G
Thermoplastic composite Panels (Heston Barrier or Similar Type)	P-G	E	P	G	G
Concrete Walls, Normal Density	G	P	E	E	G
Concrete Walls, Light-Weight (Triad Steel Corp.)	G	P-G	E	G	G
Concrete Blocks Standard	G	P	E	G	P
Concrete Blocks Perforated	G	G	E	G	P
Brick Walls	G	P	E	G	P-G
Ceramic Products	G	P-G	E	G	P-G
Lexan (Can. General Electric)	P-G	P	G	G	G-E
Gabion Walls	G	E	E	E	G
Earth Berm	E	G	E	P	E

Normally, posts are drilled or driven 1.5 to 5.5 metres into the ground, depending on the loads and soil types, and then backfilled with selected uniform compacted soil from the hole.

Alternatively, panels can be placed vertically in a trench, which is then backfilled with uniform compacted soils from the excavation. Normal trench depths range from 1.2 to 3.0 metres.

The barrier itself can be in the form of panels, planks, blocks, or any form appropriate for that material which would provide adequate attenuation and easy construction. Overlapping of panels and tongue-and-grooved planking are practices which aid in reducing gaps or cracks that lead to the reduction of sound attenuation.

4.2.3 - Reported Barrier Project Costs

The greatest proportion of the costs required for a noise barrier project is the cost of the material for the structure, which generally makes up about 70 percent of the total costs. Construction costs, site preparation, drainage corrections, special foundation designs, and earth retaining designs represent about ten to twenty percent of the overall barrier cost. Other contingencies include planning, contract administration, and inspection, which average about 16 percent of the total project cost.

A wide range of barrier costs exists when considering the large selection of materials available. Table 4.3 presents the average unit costs of several noise barriers as reported in the literature and by various manufacturers.

Table 4.3
Barrier Costs Per Square Metre
(Reported in 1980 Canadian Dollars)

MATERIALS	Height (metres) 3.0	4.5	6.0
Wood	50	45	75
Steel	55	145	155
Concrete	50	80	70
Wood/Concrete	65	65	60

These costs are based on average conditions and are not suitable for use on specific projects as actual site conditions must be considered.

Unit costs for earth berms were excluded as they are dependent on the availability of surplus earth and distance over which materials must be transported.

As noted, the unit costs vary with respect to the height of the barrier as well as the type of material used.

The nature of the noise barrier has some bearing in the total cost. On new major roads where the alignment, location, and grade of the barrier is incorporated into the design of the road, the availability of excess earth and excess right-of-way may allow for the construction of an earth berm. As a result, the costs of this barrier may be less than the costs associated with a retrofit barrier.

Although there is a slight variation in project costs from location to location, presently there is a general trend of decreasing installation costs of noise barriers. In places where there as been an ongoing noise barrier program over the last few years, such as Ontario, the demand for barriers has increased, resulting in the development of new barriers and increased experience in installation by contractors. The inherent increase in competition has had a steadying or decreasing effect on prices.

4.2.4 - Other Considerations

Besides reducing the magnitude of noise to acceptable levels, noise barriers must meet other criteria.

Before a project gains public acceptance, the appearance of a noise barrier must be aesthetically pleasing, since appearance is probably the one item by which the vast majority of the public will judge its merits. Not only will residents living adjacent to the barrier demand a functional structure, but also one that has no displeasing visual effect on their property. Material, colour, texture, and landscaping are a few characteristics which must be considered if providing an aesthetically pleasing barrier is desired, but this raises the question as to how much capital should be spent on the appearance of the barrier.

The safety of motorists and the general public must be considered in the design of noise barriers. Horizontal stopping sight distances must be maintained, especially near intersections, so that the risk of collisions is not increased. Furthermore, barriers that are near the roadway must be positioned such that they do not act as obstacles to the passing vehicles and so that corners and posts are not exposed to high speed traffic.

The construction of noise barrier walls or berms may have an adverse effect on the natural drainage pattern in the area. To overcome difficulties that may result, storm sewers, flumes, or culverts may be required. Alternatively, a simple hole at the bottom of the wall may be sufficient to allow the passage of run-off water and eliminate the threat of flooding or excess erosion. However, these holes must be acoustically baffled or the height of the wall must be increased to maintain the desirable sound attenuation.

Locating barriers in soft soils requires treatment to ensure that the walls will be stable enough to withstand expected loads. Conventional methods include the removal of the undesirable soil and backfilling with an adequate material, pile foundations, tie backs, deeper embedment, and spread footings. In any case, project costs will be greater than what normally would be expected.

Any openings required along a barrier, such as fire hose openings opposite hydrants, or doors to accommodate the passage of maintenance crews and equipment from one side of the wall to the other, will require measures to prevent excess transmission of sound. Designs, however, should be considered on a case-by-case basis, as no standards exist to maintain the sound attenuation at such points along the wall.

4.3 Barrier Priority Schemes

Implementation of a barrier program is likely to be carried out in stages dependent upon available funds. To establish the locations where barriers should be installed, and the order in which they should be installed, a barrier priority scheme must be developed.

In general, a priority scheme weights the benefits and costs of introducing a noise barrier on a site specific basis and may include such factors as:

- The existing (predicted) unattenuated noise level.
- The number of residences exposed to noise levels which cause annoyance.
- Number of years that the residential development existed before construction of the major roadway.
- The effectiveness of a barrier to reduce noise either to acceptable levels or by a predesignated minimum amount.
- The cost to construct the noise barrier.

Examples of alternative barrier priority schemes are outlined in the following sections:

(a) Ministry of Transportation and Communications, Ontario

The Ontario Government in February of 1977 embarked on a retrofit program to provide, where feasible, barriers on freeways through existing residential areas. This program was constrained by the requirement that a substantial attenuation must be achieved at a reasonable cost.

The Ministry of Transportation and Communications adopted the following criteria for residential communities which apply for noise barriers under the program:

1) The facility along which the barrier would be erected must be a freeway, at least 4 lanes in width, adjacent to residential development.

2) Permissible maximum noise level of 72 dBA Leq or lower would need to be achieved by implementing the barrier. This level would need to be achieved on the basis of traffic level of service 'C' or the average of the maximum hourly volume.

3) A noise barrier must provide a minimum of 5 dBA average attenuation.

4) Candidate sites must be based on benefit cost considerations and mutually agreed upon by the Region and Priority Development Branch of the Ministry.

Specific criteria were developed for standard Ministry barrier heights. The barrier is generally an average of 4 metres in height with flexibility of being higher or lower, but not less than 3 metres high. The standards for construction and reconstruction of barriers could take the form of either walls, earth berms or a combination of both.

The Ministry of Transportation and Communications identified 160 potential noise barrier sites on freeways that were adjacent to residential development on the basis of field measurements and records of complaints.

As it was both physically and financially impossible to construct barriers at all locations, a barrier priority scheme was derived using a benefit/cost index. The numerical relationship of that index number increases directly with the amount of noise attenuation to be provided by the barrier and the number of residences to be protected.

In detail, the index number = $\frac{\text{Benefit} \times 1000}{\text{Cost}}$ Where,

Benefit = $\sum_{i=1}^{n} \Delta Li \, (Li - 57)$

Cost = cost of barrier and associated work expressed in dollars.

n = number of residences affected with existing (predicted) noise levels that exceed 57 dBA Leq.

Li = existing (predicted) noise level at each residence 1.3 m (4') above the ground in the recreational area of the property.

57 = desirable noise level in dBA over a one hour period at a traffic level service C.

Δ Li = noise attenuation provided by a barrier for each residence.

(b) Minnesota Department of Transportation

The barrier priority scheme developed by the State of Minnesota is described as follows:

Ner = (He/R1) x Rar Where,

Ner = The noise exposure rating.

He = The number of first row homes exposed to a given noise level.

R1 = The residential length in miles.

Rar = The relative annoyance rating and is defined by first calculating the L10 values then utilizing the axiom that a 10 decibel increase results in a doubling of loudness. (For example an L10 of 60 dBA represents a Rar of 1. An L10 of 70 dBA represents an Rar of 2 and L10 for 80 dBA equals an Rar of 4.

The Department of Transportation for the State of Minnesota has calculated Ner values for 167 sites in the Minneapolis/St Paul Metropoïitan Area.

(c) Maryland State Highway Administration

In developing a priority scheme for its highway barrier retrofit program, the State of Maryland has devised a relatively simple method which relies on the accummulation of points on a site specific basis:

1) 5 points are awarded for each year that a development has existed since the highway was opened.
2) 1 point is awarded per residence in the 71 to 75 dBA (L10) range.
3) 3 points are allotted per residence in the 76 to 80 dBA (L10) range.
4) 9 points are allotted per residence impacted by noise in excess of 80 dBA (L10).
5) For schools the respective points for the above ranges are 10, 30 and 90.
6) For churches the respective points are 3, 9 and 27.

(d) Connecticut Department of Transportation

The State of Connecticut Transportation Department has developed a Project Priority Rating Number (PPRN). This method of prioritizing project locations involves determining the ratio of a benefit factor (BF) and the total project cost times 1000. The benefit factor is defined as follows:

$BF = (Pi \times n_b \times Sf) + 1/3 (Pi \times n_a \times Esf)$

Pi = The project effecitveness index.
An L10 value of 60 dBA has a Pi of 3.33, and for each dBA increase in L10, Pi increases by a factor of 3.

n_b = The number of homes in place before the highway was constructed, which are expected to receive benefits.

n_a = The number of homes constructed after the highway was in place, which are expected to receive benefits.

Sf = The sensitivity factor which is 1.5 for land uses which follow within a given category for serenity and quiety are of great significance.

Esf = Factor = 1 for residences, schools, churches and hospitals.

(e) California Department of Transportation

The retrofit priority scheme in the State of California assesses abatement cost, abatement potential and the number of dwelling units to be protected.

Priorities are assigned on the basis of whether;

- The residences were in place prior to the selection of the highway route,
- The residences were in place prior to the construction of the highway or,
- The residences were constructed after the highway was in place.

The control of highway noise is given a higher priority if the dwellings were in place prior to the construction of the highway.

The priority index is described as follows;

$$\text{Index} = \frac{\Delta L \times (Li-70)^2 \times N}{\text{Cost}}$$, where

ΔL = Unattenuation in dBA provided by the barrier,

Li = Unattenuated noise level expressed in units of dBA (L10),

N = Number of residences affected with noise levels in excess of 70 dBA (L10), and

Cost = Cost of noise attenuation project in thousands of dollars.

(f) New York Department of Transportation

The State of New York developed a barrier retrofit program in 1979. Their program involved a 7 phase plan. The first phase produced a listing of 601 Interstate highway segments representing 1400 miles of Interstate Highway in New York State.

Phase 2 provided preliminary L10 levels for each of the segments identified in Phase I. All segments wherein noise levels did not exceed 70 dBA (L10) were eliminated. There remained a total of 160 segments.

Phase 3 involved an initial field reconnaissance of eligible sites. Sites with topographic constraints or where receptor density was not conducive to a retrofit barrier program were eliminated.

Phase 4 involved a detailed field reconnaissance of topography and receptor density to provide data for computer analysis and estimation of a cost benefit indicator.

Noise measurements were carried out in Phase 5 to validate and refine predictions and to further refine the priority listing.

In Phase 6 a final list of project sites and of cost-benefit indicators was prepared.

In the final or seventh phase a total potential cost for retrofitting all of the sites was developed.

4.4 Program Costs and Financing

There exists a considerable difference in the expenditures which various jurisdictions spend, or are willing to spend on noise barrier programs. For many jurisdictions, the development of barriers relates to new residential construction and is frequently the responsibility of developers. In the case of new roadway construction, noise is considered in the design stages and the costs of appropriate noise mitigation measures are the responsibility of the agency developing the facility.

4.4.1 - Program Costs

Although a concerted attempt was made to research costs directly related to retrofit programs, many agencies were unable to provide a dollar breakdown of expenditures dealing with retrofit as opposed to new installations. As a result, program costs are covered under jurisdictional headings.

(a) United States

On the federal level, a study sponsored by the Federal Highway Administration Synthesis Committee entitled Highway Noise Barriers is presently underway to determine the situation regarding existing noise barriers and also any proposed programs and related budgets. Unfortunately, those figures have not yet been received. However in 1976, the Federal Highway Administration (FHWA) determined that in seventeen states, fifty-three kilometres of noise barriers had been constructed at fifty-one locations totalling $12 000 000. In addition, 15.5 kilometres of the barriers were in the design stages at 22 locations over 13 states for a cost of $3 000 000. The length of barrier ranged from 71 metres to 5 790 metres, with a height of 0.9 to 7.9 metres at an average cost of $220 per linear metre installed.

In 1977, the FHWA estimated that it would cost 278 million dollars to finance noise abatement projects, including barriers and building insulation, for existing links in the interstate highway system. The FHWA also predicted that it would cost 150 million dollars for barrier construction along new highways in the system for a total cost of 428 million dollars for the entire noise barrier program (in 1977 dollars). However, these figures represent a program to which the agency is not committed, but are used to illustrate the existing situation regarding noise control and the magnitude of ensuing problems.

Table 4.4 illustrates the amount of money that has been spent on barrier construction programs in various states and in one municipality, and the budget allocated to future retrofit and barrier construction purposes.

Table 4.4

Barrier Cost Experience in the United States

Agency	Program Initiation Date	$ Spent	Future Budget
California	1976	$72 000 000	$18 000 000/Year for the next 2 years
Connecticut	1975	$1 500 000	$100 000 as part of a new project
Maryland	1980	NIL	$10 to 15 million over next 2 years
Michigan	1974	$3 000 000	$2.5 to 3 million over next 2 years
Minnesota	1972	$25 000 000	Pending report or future of program before the legislature
New Jersey	1980	NIL	$1 500 000 during 1980
Ceritos, Calif.	early 1970's	UNKNOWN	$6 to 7 million for 34 000 feet of retrofit wall

(b) West Germany

A proposal to protect people in residential and commercial areas against traffic noise was adopted by the Cabinet of West Germany on December 21, 1977. The proposal calls for approximately $221 million to be committed in Federal and State funds to construct noise protection walls and double glazed windows in building fronting on public roads. No breakdown of these costs was readily available so as to determine costs related to barrier design.

(c) Canada

With the exception of, the Canada Mortgage and Housing Corporation which provides financing for new residential dwellings which meet specified noise guidelines (refer to Section 3.3), agencies at the federal level do not actively participate in noise barrier programs.

Of the ten provinces, only Ontario actively promotes a noise barrier retrofit program.

The Ministry of Transportation and Communications (MTC) for the Province of Ontario has set a five million dollar budget for retrofit over the next five years in the province. It was proposed that the expenditure of this money would be at the rate of $1 million per year. This rate of expenditure may vary, however, due to delays in construction of certain projects.

In addition to the funds allocated for a retrofit program, approximately $2.5 million has been approved for noise abatement measures provided during the construction of a highway through existing residential areas.

4.4.2 - Financing

Within the United States, many noise barriers are financed through a funding formula wherein the Federal government and State government share the costs out of the general taxation revenue. The funding formula is ninety percent federal funds and ten percent state fund for highway projects.

The state of Minnesota through 1975 legislation was able to pass a law requiring that one percent of the gasoline tax be spent on noise barriers. This amounts to approximately one million dollars per year.

Those few municipalities involved in barrier retrofit programs require either provincial or state assistance in the development of their barrier retrofit program. Ceritos, California, however, indicated that it was able to fund retrofit barriers with public funds through a redevelopment agency. The telephone interview survey indicated that it might be possible for municipalities to consider the construction of noise barriers as they would any other capital improvement project, such as the installation of sidewalks.

4.5 Benefits and Disbenefits

In addition to deciding whether a barrier will be useful in mitigating noise to a desired level or whether it would be feasible economically, it is also necessary to consider the following factors.

1. non-accoustical benefits
2. property needs;
3. public acceptance (marketability/aesthetics);
4. maintenance costs;
5. potential safety problems;
6. energy concerns;
7. implementation.

4.5.1 Non-Accoustical Benefits

Non-accoustical benefits which may result from the construction of a barrier include a reduction in such factors as fumes, dust and dirt, annoyance attributed transients and headlight glare, vibration, salt spray, apprehension of the potential of vehicles leaving the road pavement and an increase in privacy. Surveys have been conducted to ascertain the relative importance of each of these factors to residents. The aggregated results of such surveys are presented in Figure 4.1. As illustrated, respondents report greater annoyance attributed to noise than any other single issue. On a scale of 100 noise generally receives an annoyance rating of approximately 45 points. Annoyance ratings assigned to dust and dirt, vibration and fumes are generally lower yet significant, ranging between 10 and 15 points. On average, annoyance attributed to the other specified issues is generally not significant.

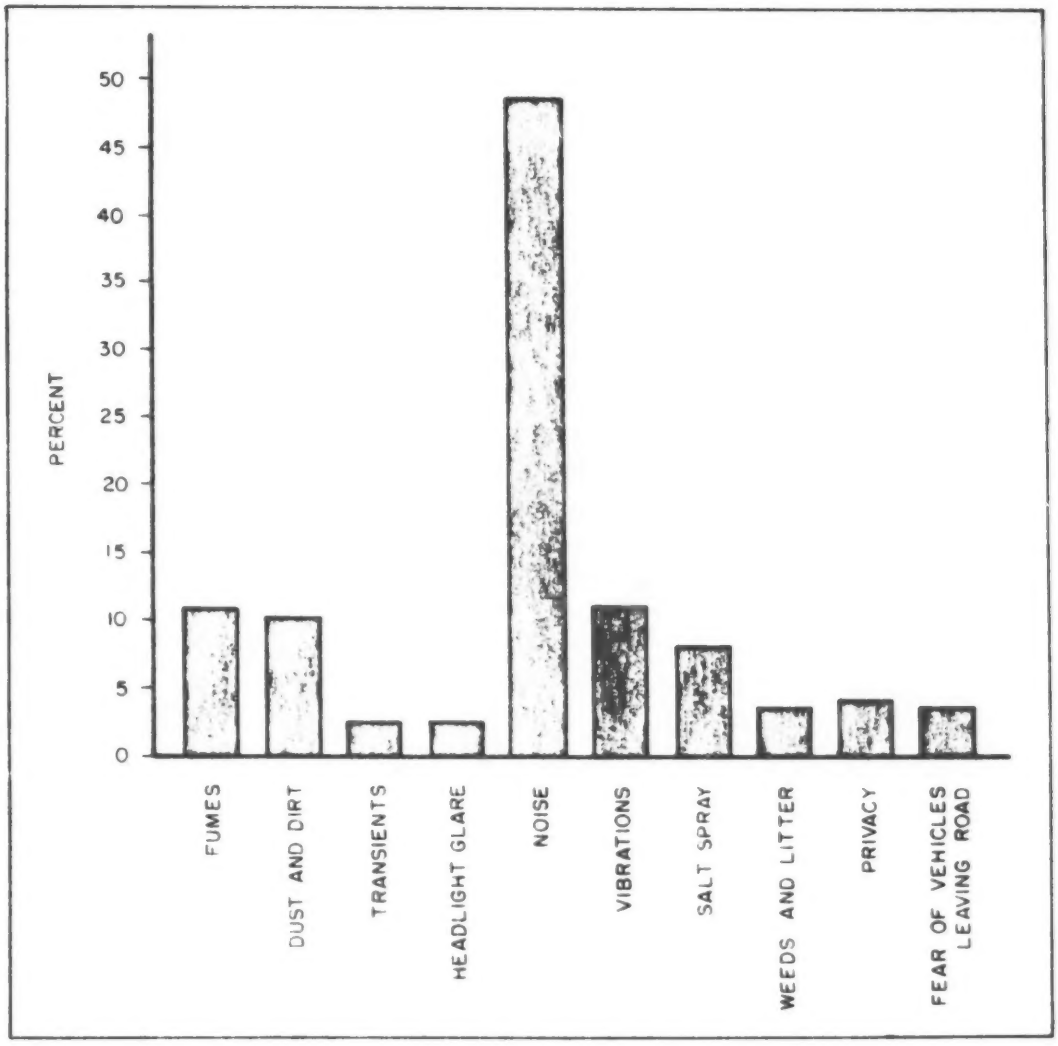
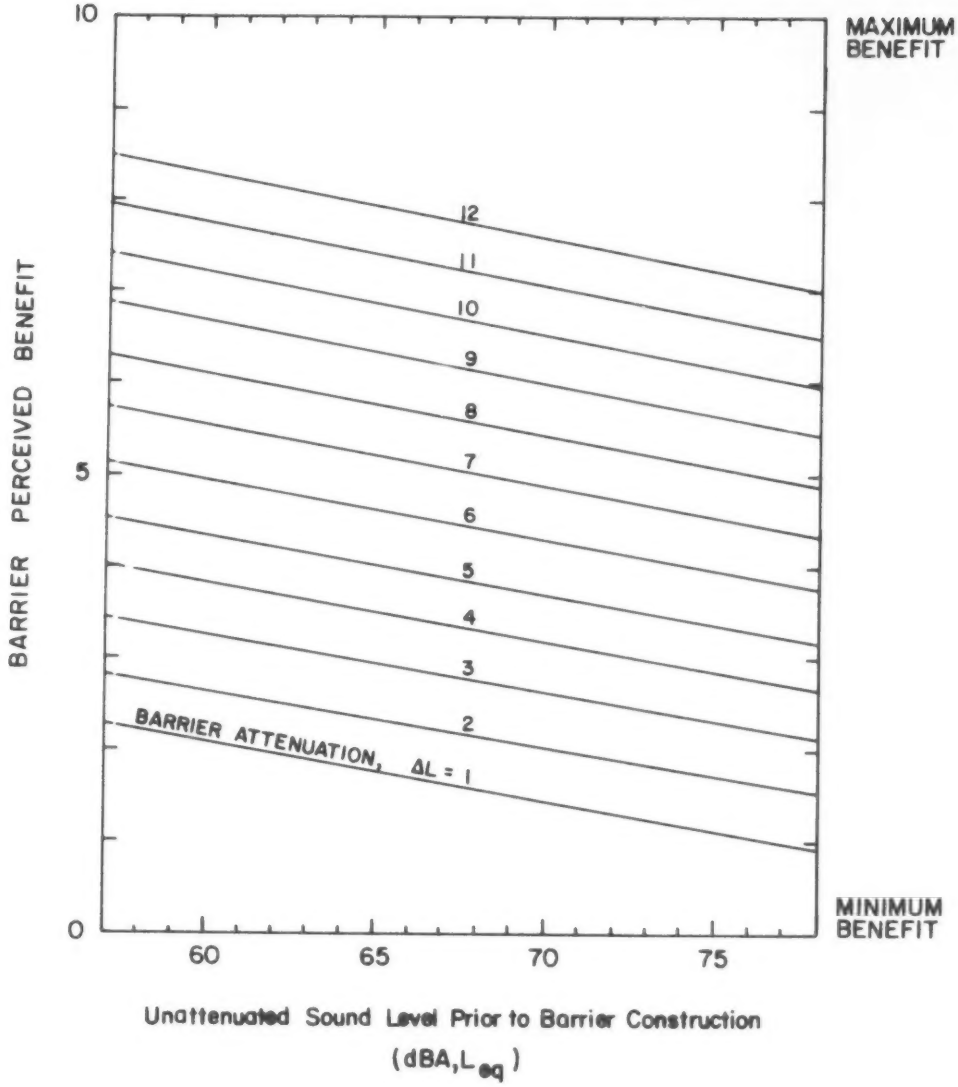


Figure 4.1
Rating of Roadway Annoyances
(Ref: 60)

Figure 4.2 enables one to determine the perceived barrier benefit on a scale of 0 to 10, given a knowledge of barrier noise reduction and the unattenuated sound level. The results of such laboratory studies address only the noise related barrier benefit and excludes other non-acoustic factors.



Barrier Perceived Benefit
(Ref: 63)

Fig. 4·2

4.5.2 - Property Needs

In some situations it may be possible to include a berm and barrier combination or possibly a berm by itself. An earth berm requires a considerable amount of land as the generally recommended slope ratio is 3:1. This ratio ensures ease of maintenance and will ensure a stable slope. In some situations it may be possible to reduce the slope, however, in such cases consideration must be given to maintenance and safety requirements as well as to the stability of the material forming the berm.

In the majority of cases, accoustical wall barriers require only a minimal amount of space likely in the order of one metre to permit maintenance. In some situations the wall may be of such a height that a wider space is required to accommodate equipment for maintenance and structural reinforcement.

4.5.3 - Public Acceptance (Marketability/Aesthetics)

The existence of a noise barrier, whether it be a berm or a wall is indicative to homeowners that a noise problem exists in the area. Some consumers may regard this as a negative selling feature while others may perceive the wall and berm as offering a "guaranteed" level of protection from noise and additional privacy.

Care must be taken to provide sufficient aesthetic treatment and to avoid a tunnel effect. Such effects have been reported along freeways and highways by many jurisdictions. Because of the required height of acoustic barriers, their inclusion along arterial roadways, which may be narrower than freeways and highways, could result in a more severe tunnel effect.

Information received indicates that in Washington, D.C. the Fine Arts Committee would likely oppose the construction of barriers even if the jurisdiction determined that they were necessary. (The Fine Arts Commission in Washington is responsible for ensuring that the Capital city looks "pleasing to the eye" of the visitor.)

In several municipalities in California careful consideration has been given to the construction of acoustical barriers. Specifically, in Ceritos, California, the walls are constructed of slump block which provides a pleasing texture to the eye. These walls are a beige and buff colour considered attractive in that particular locale.

4.5.4 Maintenance Costs

Maintenance costs associated with earth berms include the cost of mowing grass, weed control, and maintenance of landscaping. Both berms and walls require some costs which can be associated with "clean-up" around these obstacles. The fact that these walls and berms are barriers to noise also results in them being barriers to local winds which carry dust and debris.

Barriers located in close proximity to the roadway edge of pavement are occasionally likely to be damaged by automobiles and a replacement costs are likely to be incurred.

Berms or walls may also act as barriers to surface water drainage thus incurring additional maintenance costs.

Many jurisdictions find it preferable to locate acoustical barriers on the publicly owned portion of lands thus assuring the retention of the noise barrier and regular maintenance.

There may exist some concern on the part of a municipality to assume responsibility and ownership for noise barriers, for unlike park maintenance, not all residents benefit from the construction of a noise barrier.

An interesting approach to maintenance exists in some municipalities within the State of California. Local community groups, comprised of approximately 80 to 100 persons assume responsibility for the maintenance of common grassed areas and acoustical barriers. Membership in the local community group is mandatory and the group is responsible for lobbying its members support to ensure that appropriate maintenance is carried out.

4.5.5 - Energy Concerns

The construction of an acoustical barrier may in some situations shield dwellings from prevailing winds. Such shields may result in a reduction in spacial heating costs. Alternatively, it is possible that the construction of noise barriers could magnify local wind effects and thus increase spacial requirements.

Another energy concern may be that the construction of an acoustical barrier could result in reduced solar exposure which may not be acceptable to residents.

4.5.6 - Potential Safety Problems

Potential safety problems with respect to acoustical barriers exist. In many situations the barriers may have to be located in close proximity to roadways to be effective. In so doing, a potential for automobile accidents is created.

Although the potential safety problem to children playing on berms or near barrier walls is minimal, it might be worth considering in evaluating a given acoustical barrier.

4.5.7 - Implementation

In implementing an acoustical barrier program there may be concern with respect to the local land use (zoning) bylaw which may limit the height of the fences and in turn limit the height of the acoustical barriers.

In the actual implementation of any barrier program there will be concerns, such as the method and manner of financing, which may cause some concern for the municipality.

Because not all barriers can be erected at once, there will be need to develop some sort of priority program. Such a program may result in some inequities.

5. Policy and Cost Analysis

5. POLICY AND COST ANALYSIS

A preliminary assessment of arterial roadway traffic noise levels in the City of Edmonton was undertaken as a first order attempt to narrow the range of potential residential noise standards and to identify related policy implications and costs. The assessment consisted of an investigation of traffic noise levels at the ground storey for all existing residential densities and of the effectiveness of noise barriers in reducing the traffic noise within these areas to selected design levels.

The intent of the assessment was not to suggest that noise barriers are the only means of attenuating unwanted sounds. In fact, there are a number of available alternatives including traffic management, architectural treatment, double glazing and air conditioning of residential units. The intent of the assessment was simply to illustrate the need for and magnitude of noise attenuation requirements at selected design standards as well as the focus on associated implications such as costs and the alternative means of attenuation. The analysis was based on readily available data including recorded traffic volumes, vehicle classification counts and proven traffic noise projection techniques. No actual noise measurements were undertaken.

5.1 1980 Arterial Roadway Traffic Noise Levels

5.1.1 - Methodology

1980 traffic noise levels on all arterial roads within existing residential areas were estimated by the Transportation Systems Design Department of the City of Edmonton using the prediction techniques outlined in the Alberta Surface Transportation Noise and Attenuation Study. To calculate these noise levels the following data was collected by City staff. The Consultant assisted in the processing of the data into a format appropriate for input into the noise prediction model.

a. Vehicle operating speeds
b. Roadway volumes by vehicle classification and by time of day,
c. General roadway characteristics, and
d. Receiver setbacks from the roadway.

(a) Vehicle Operating Speeds

Operating speeds on all road segments were assumed to be equal to the posted speed limit.

(b) Roadway Volumes

Roadway volumes were estimated using available traffic data including 1978 and 1979 average annual weekday traffic volumes, historical growth rates, hourly volume distributions, hourly classification counts of the number of cars, medium trucks and heavy trucks for each of the following arterial roadway categories;

- Non truck route
- 24-hour truck route
- 13-hour truck route (7:00 a.m. to 8:00 p.m.)
- 16-hour truck route (7:00 a.m. to 11:00 p.m.)

To achieve the greatest accuracy possible with the data available, total roadway volumes and vehicle classifications were estimated separately using linear regression and other analytic tools for each of four time periods;

- Peak hours (7:00 a.m. to 9:00 a.m. and 4:00 p.m. to 6:00 p.m.)
- Daytime off peak (9:00 a.m. to 4:00 p.m.)
- Evening (6:00 p.m. to 10:00 p.m.)
- Nighttime (10:00 p.m. to 7:00 a.m.)

(c) General Roadway Characteristics

All road sections under study were assumed to have the following characteristics in common; gradients of less than two percent, normal pavement surface texture and pavement elevation at grade with adjacent residential lands. No adjustments were assumed for the effect of interrupted flow at intersections, for shielding due to vegetation, ground attenuation or structures located adjacent to the roadway.

(d) Receiver Setbacks

The distance between the noise source and receiver was assumed constant at 30 metres (100 feet) from the centreline of the road.

5.1.2 - Unattenuated Noise Levels

Outdoor noise levels at the ground storey were calculated using the methods and data described above. The results are expressed in terms of a single descriptor, an A-weighted energy equivalent day-night sound level, dBA Ldn. This descriptor is derived by averaging time varying sound energy over the daytime (7 a.m. - 10 p.m.) with the time varying sound energy over the nighttime (10 p.m. - 7:00 a.m.) to which an additional ten decibel weighting is applied.

Figure 5.1, illustrates the 1980 arterial roadway traffic noise levels adjacent to all existing residential areas within the City of Edmonton. The noise levels are represented by bands of varying shades. The lightest shade represents sound levels of 55 dBA, Ldn or less. The darkest shade represents sound levels ranging between 70 and 75 dBA Ldn. Sound level bands are shown only adjacent to residential areas. Hence in locations where residential land uses exist on only one side of the road, the band is plotted on that side only. Where residential land uses exist on both sides of the road, the bands are plotted on both sides. For clarity, noise levels in the downtown area and adjacent to the James MacDonald Bridge have not been shown. Noise within these areas has, however, been included in the analysis.

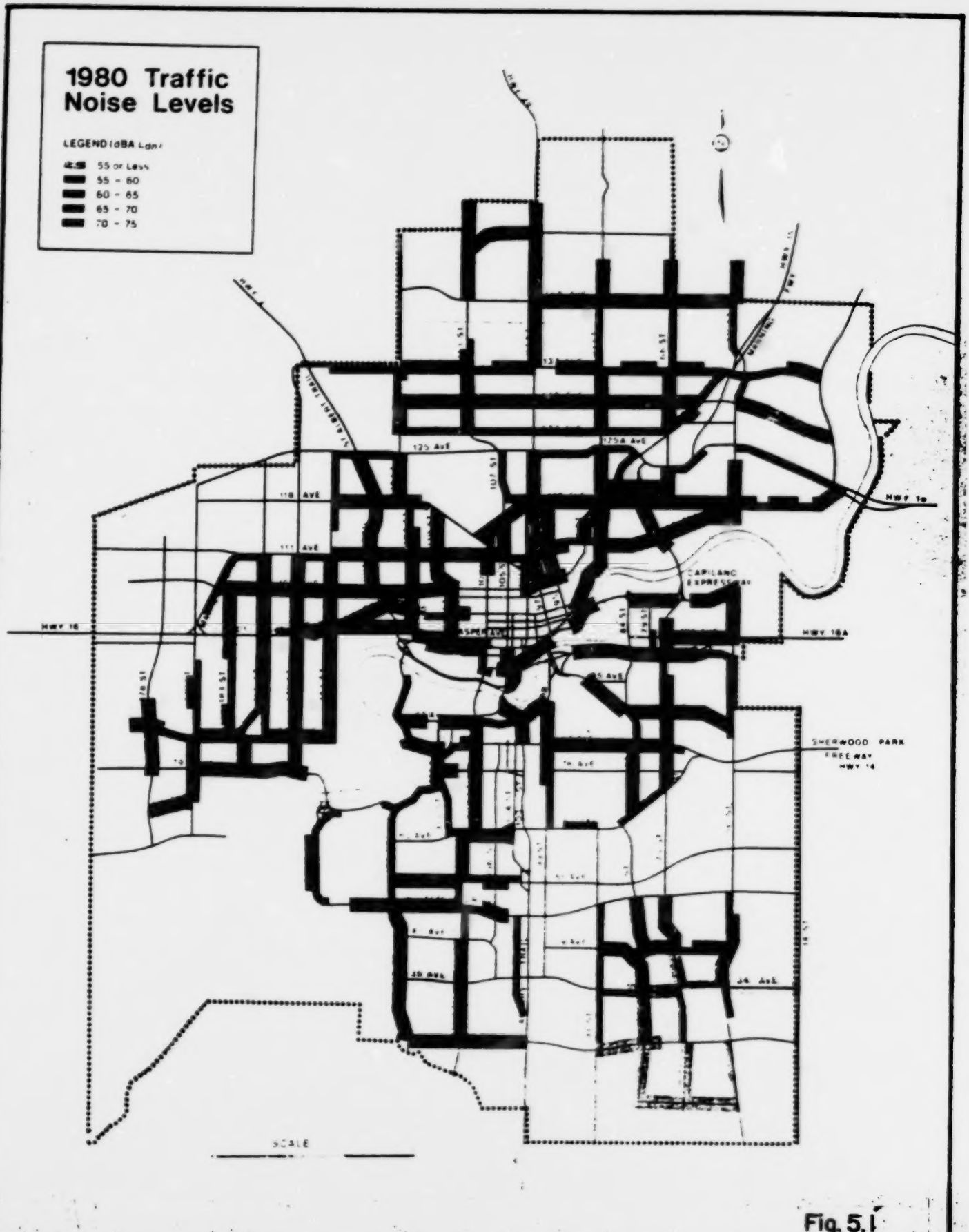

1980 Traffic Noise Levels
LEGEND (dBA Ldn)
55 or Less
55 - 60
60 - 65
65 - 70
70 - 75
HWY 16
HWY 16A
HWY 14
SHERWOOD PARK FREEWAY
CAPILANO EXPRESSWAY
125 Ave
118 Ave
111 Ave
107 St
105 St
97 St
SCALE

Fig. 5.1

Within this preliminary exercise, no adjustments were assumed for noise attenuation which is provided by existing barriers or by dwellings located adjacent to the roadway. However, such allowances are to be assessed in the Stage II study.

The limited amount of traffic data available particularly during the nighttime hours results in a substandial error on some roads. However, the magnitude of this error is considered acceptable for this first order analysis of noise exposure. For a more detailed investigation such as that proposed in Stage II, or for barrier design purposes, the collection of additional traffic data and a further assessment of traffic noise levels would be warranted.

5.2 Exposure to Traffic Noise

The number of people living adjacent to each arterial road was estimated using land use data from the Transportation System Plan, supplemented by a local awareness of the City and its immediate environs. Residential land uses were classified according to one of three density categories as follows;

- Low Density (single family, duplex and townhouses)
- Medium Density (walkup apartments) and
- High Density (highrise apartments)

The population within each category was estimated using average densities derived from the City of Edmonton Planning Department report entitled, "A Guide to Residential Densities", September 1977. Population densities assumed for this study were; single family dwellings -25 persons per acre, duplexes and townhouses -50 persons per acre, walkup apartments -100 persons per acre and highrise apartments -240 persons per acre.

The portion of the population exposed to arterial roadway traffic noise was estimated on the basis of an assumed percent exposure ranging from 75 to 100 percent depending on land use density and building orientation. As illustrated in Table 5.1, there are

Table 5.1

Estimated Population Exposed To Arterial Roadway Traffic Noise

Residential Density	1980 Traffic Noise Levels (dBA, Ldn)						Total Number of People Impacted
	55 or less	55-60	60-65	65-70	70-75	Greater Than 75	
Low	5 000	7 500	21 000	12 500	10 500	0	56 500
Medium	10 000	6 500	14 500	11 500	9 000	0	51 500
High	3 500	2 500	8 500	4 500	3 000	0	22 000
TOTAL	18 500	16 500	44 000	28 500	22 500	0	130 000

approximately 130 000 persons who reside within 30 metres of arterial roads who are exposed to arterial roadway traffic noise. Of these approximately 18 500 persons experience outdoor levels less than or equal to 55 dBA Ldn and approximately 16 500 persons experience outdoor levels ranging between 55 and 60 dBA Ldn. The remaining 95 000 persons experience outdoor levels ranging between 60 and 75 dBA Ldn. No persons are reported to experience traffic noise levels in excess of 75 dBA Ldn. These results are also illustrated graphically in Figure 5.2 entitled "1980 Arterial Roadway Traffic Noise Exposure."

5.3 Residential Lot Formats

Four residential lot formats are commonly found in the City of Edmonton. These formats are referred to as;

a. Backing-On
b. Frontage Road
c. Flanking (Side Oriented)
d. Fronting

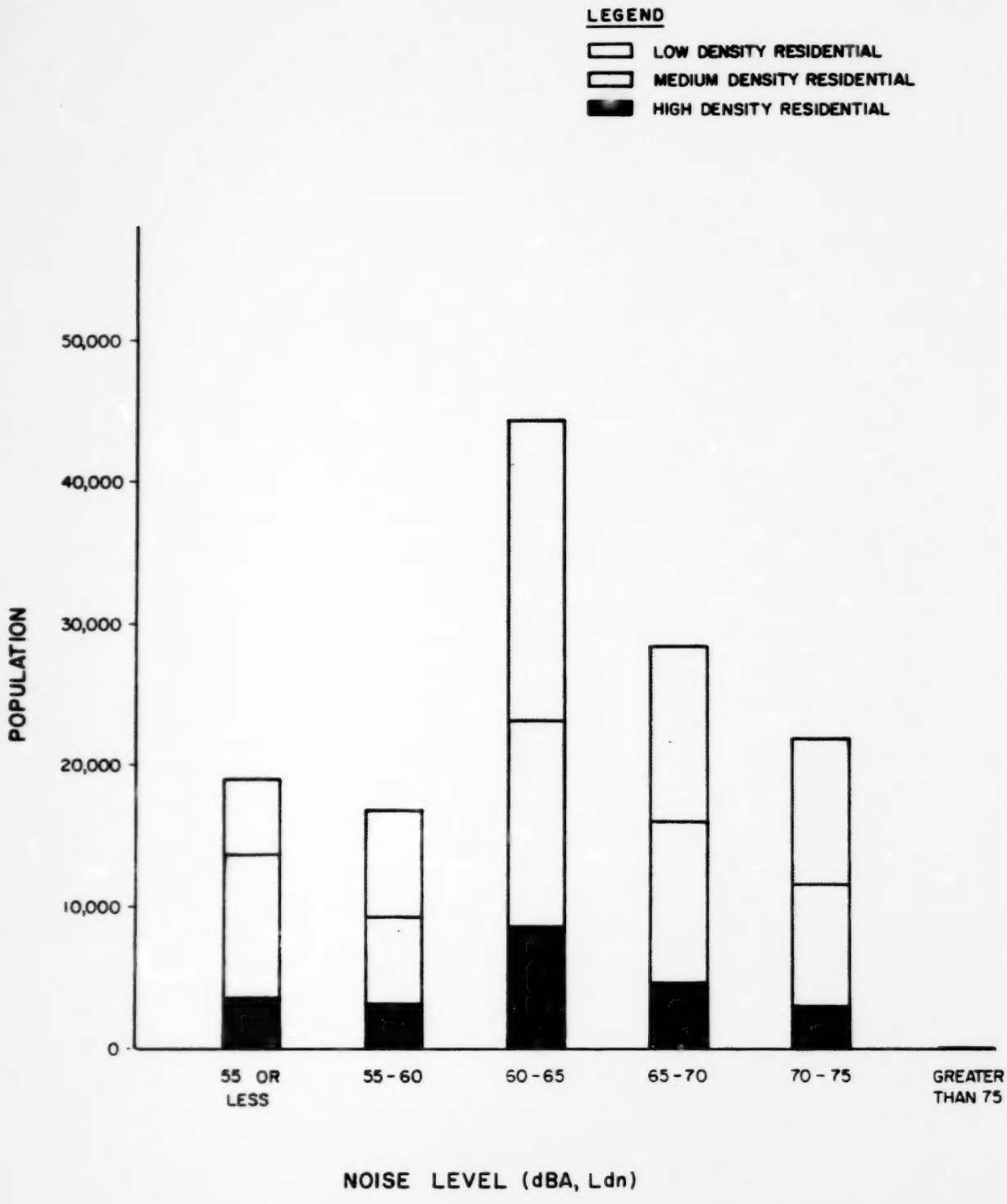
A brief description of these lot configurations and of the feasibility of constructing a continuous barrier on each follows:

(a) Backing-On

In this configuration, the backyard faces the major road. A lane may or may not run between the two. In most cases a continuous noise barrier can be constructed on the property line between the backyard (or lane) and the roadway.

(b) Frontage Road

In this configuration the front of the house faces the arterial road. Between the lot and the arterial road there exists a local or frontage road and landscaped boulevard. The width of the



1980 Arterial Roadway
Traffic Noise Exposure

Fig. 5·2

boulevard may vary however in most cases it is possible to construct a continuous noise barrier on this boulevard. It may or may not be necessary to include guardrails along the sides of the barrier.

(c) Flanking (Side Oriented)

Lots flanking onto the arterial road are generally bounded by a local road in front of the house and a lane behind. In most cases it is not feasible to construct a continuous barrier along the limit of the arterial roadway allowance without acquiring additional lands or eliminating access to lanes.

(d) Fronting

In this configuration the lot abuts the arterial road and the front of the house faces it directly. The feasibility of constructing a continuous noise barrier along the property line is precluded by the numerous driveways which must be retained to provide access to dwellings.

Illustrated in Figure 5.3 are all the existing residential areas which abut arterial roads categorized by lot format. Also shown, are all the road sections where currently, barriers exist or where there are commitments for the construction of noise barriers.

Table 5.2 presents the estimated number of persons residing adjacent to arterial roads categorized by residential density and by lot configuration.

Of the estimated study area population, approximately 35 000 persons reside on lots backing onto arterial roads. Approximately 14 000 persons reside on lots abutting frontage roads and approximately 81 000 persons reside on lots which either front or flank onto arterial roads. These results are presented graphically in Figure 5.4.

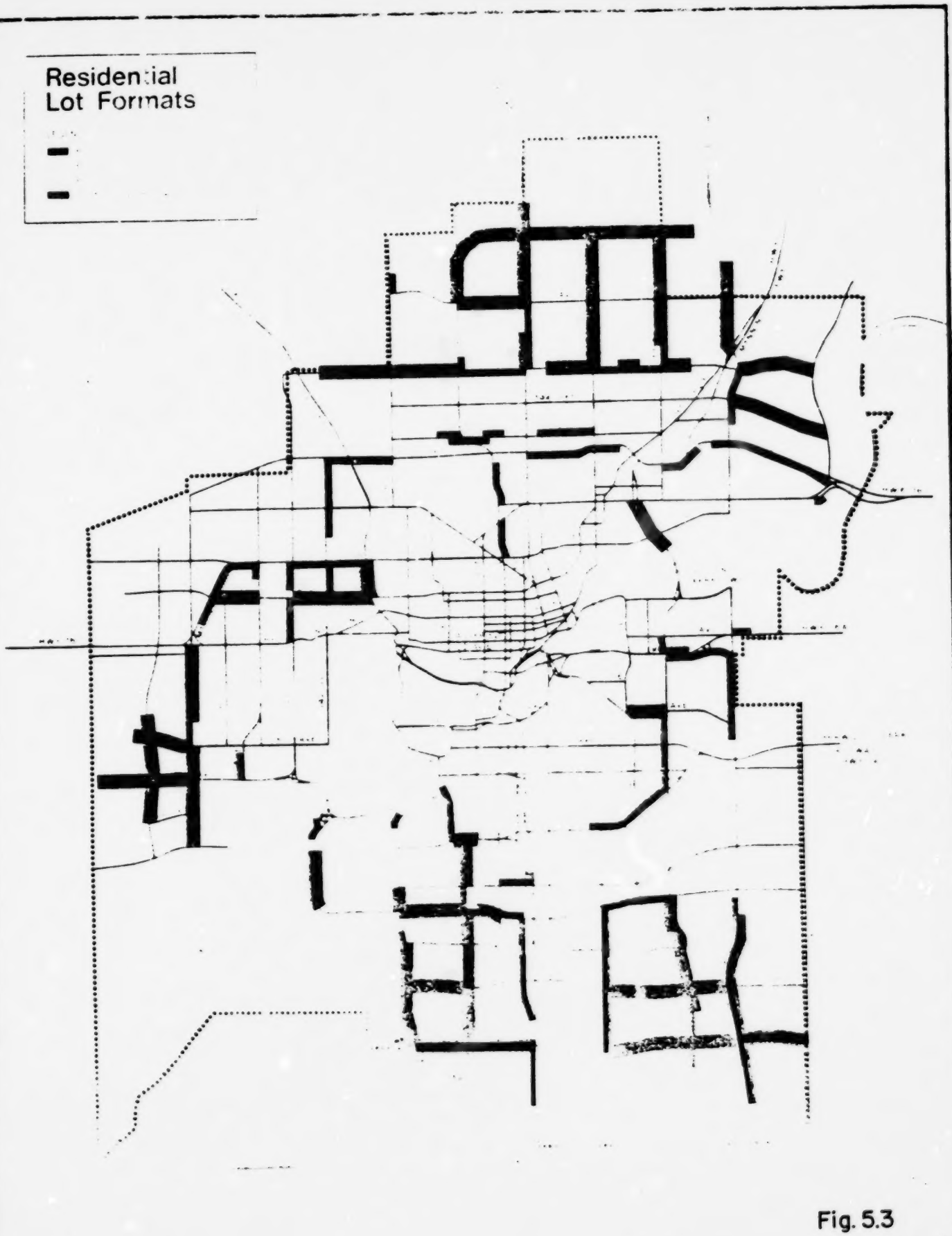
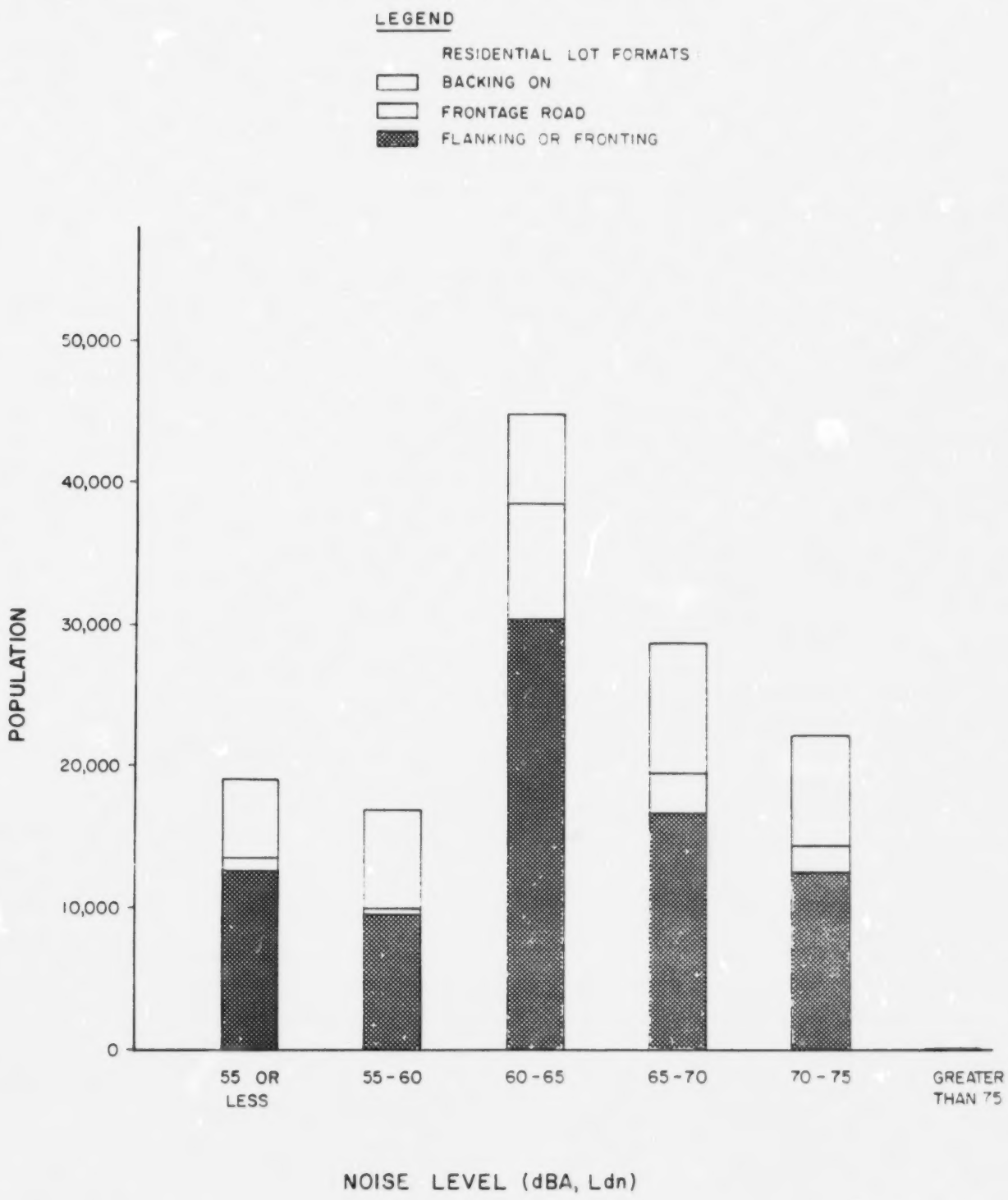


Fig. 5.3

Table 5.2
Estimated Study Area Population Categorized by Lot Format

Residential Lot Format	Density	1980 Traffic Noise Level (dBA, Ldn) 55 or Less	55-60	60-65	65-70	70-75	Greater Than 75	Total
Backing on	Low	2 000	3 500	3 500	6 000	6 500	0	21 500
	Medium	2 500	3 000	2 500	3 500	1 500	0	13 000
	High	500	0	0	0	0	0	500
	TOTAL-No.	5 000	6 500	6 000	9 500	8 000	0	35 000
	-%	14.3	18.6	17.1	27.1	22.9		100.0
Frontage Road	Low	1 000	500	6 000	2 000	1 000	0	10 500
	Medium	0	0	2 000	500	1 000	0	3 500
	High	0	0	0	0	0	0	0
	TOTAL-No.	1 000	500	8 000	2 500	2 000	0	14 000
	-%	7.1	3.6	57.1	17.9	14.3		100.0
Flanking or Fronting	Low	2 000	3 500	11 500	4 500	3 000	0	24 500
	Medium	7 500	3 500	10 000	7 500	6 500	0	35 000
	High	3 000	2 500	8 500	4 500	3 000	0	21 500
	TOTAL-No.	12 500	9 500	30 000	16 500	12 500	0	81 000
	-%	15.4	11.8	37.0	20.4	15.4	0	100.0
TOTAL - No.		18 500	16 500	44 000	28 500	22 500	0	130 000
- %		14.2	12.7	33.9	21.9	17.3	0	100.0



Population Categorized By Lot Format

Fig. 5·4

5.4 Policy Impacts

Five alternative noise levels were selected as potential residential noise standards. These levels are identified as 55, 60, 65, 70 and 75 dBA, Ldn. For each level, estimates are made of the number of persons exposed to excess noise after the implementation of a barrier retrofit program. For purposes of this exercise, the construction of continuous noise barriers is assumed to be feasible on all lots which either back on or are separated from arterials by a frontage road. The construction of continuous noise barriers is assumed not to be feasible on lots which either front or flank onto arterial roads.

Whereas, barriers may offer an effective means for protecting both low density single storey dwellings and the ground floor of medium and high density multiple storey dwellings, in general other means of noise attenuation are usually employed for the protection of medium and high density multiple storey dwellings. These other measures may include traffic management and control, building modification and air conditioning.

For purposes of this Stage I analysis, the barrier scenario is adopted as a surrogate for these other measures and it is assumed that all residents gain some benefit as a result of their construction. Benefits to be gained by residents living at the ground storey would likely be greater than those to be achieved by residents living at higher storeys who frequent the ground storey for shorter durations ie; social-recreational activities. The other means of noise attenuation identified previously are to be addressed in Stage II of the study.

5.4.1 - Attenuated Noise Levels

The number of persons exposed to excess noise before and after the construction of noise barriers is presented in Table 5.3.

Table 5.3

Estimated Population Exposed to Arterial Roadway Traffic Noise

	1980 Traffic Noise Levels (dBA, Ldn)						
	55 or less	55-60	60-65	65-70	70-75	Greater Than 75	Total
Current Conditions	18 500	16 500	44 000	28 500	22 500	0	130 000
With a Barrier Retrofit Program Designed to Reduce Noise to:							
55 dBA, Ldn	43 000	28 000	30 000	16 500	12 500	0	130 000
60 dBA, Ldn	18 500	33 000	49 500	16 500	12 500	0	130 000
65 dBA, Ldn	18 500	16 500	51 500	31 000	12 500	0	130 000
70 dBA, Ldn	18 500	16 500	44 000	28 500	22 500	0	130 000
75 dBA, Ldn	18 500	16 500	44 000	28 500	22 500	0	130 000

The implementation of a barrier retrofit program at a design standard of 55 dBA, Ldn would result in the following changes. Approximately 43 000 persons would be exposed to outdoor noise levels less than or equal to 55 dBA, Ldn, approximately 28 000 persons would be exposed to outdoor levels ranging between 55 and 60 dBA, Ldn and approximately 59 000 persons would be exposed to outdoor levels ranging between 60 and 75 dBA, Ldn.

Similar changes would be affected via the implementation of barrier retrofit programs at design standards of 60 and 65 dBA, Ldn. No changes would likely be effected if the selected design standards were 70 dBA, Ldn or greater. As shown in Table 5.3, levels in excess of 70 dBA, Ldn represent current conditions.

These findings are based on the following assumptions which were adopted on the basis of documented noise level surveys conducted at many sites before and after barrier implementation;

- Barriers are not likely to be constructed in areas where noise levels are within five decibels of the objective standard.

- In 75 cases out of 100, a properly designed barrier would eliminate excess noise of up to 15 decibels completely,

- In 25 cases out of 100, a properly designed barrier would reduce excess noise of up to 15 decibels to an excess within 0 to 5 decibels of the objective standard,

- In 50 cases out of 100, a properly designed barrier would eliminate excess noise of 15 to 20 decibels completely, and

- In 50 cases out of 100, a properly designed barrier would reduce excess noise of 15 to 20 decibels to an excess within 0 to 5 decibels of the objective standard.

The policy impacts of each of the five selected standards are also presented graphically in Figures 5.5 to 5.9 respectively. These figures exhibit the estimated number of persons within the study area who are likely to be within the objective standard or who are likely to be exposed to excess noise after the implementation of a barrier retrofit program.

55 dBA, Ldn is the most stringent of the standards proposed and exhibits the greatest number of persons likely to be exposed to excess noise.

The least stringent standard is 75 dBA Ldn. Selection of this standard would result in no one being exposed to excess noise.

5.4.2 - Noise Exceeding Policy Levels

Presented in Figures 5.10 to 5.13 are maps illustrating all existing residential areas which abut arterial roads where noise levels would exceed the selected policy level standard after the implementation of a barrier retrofit program.

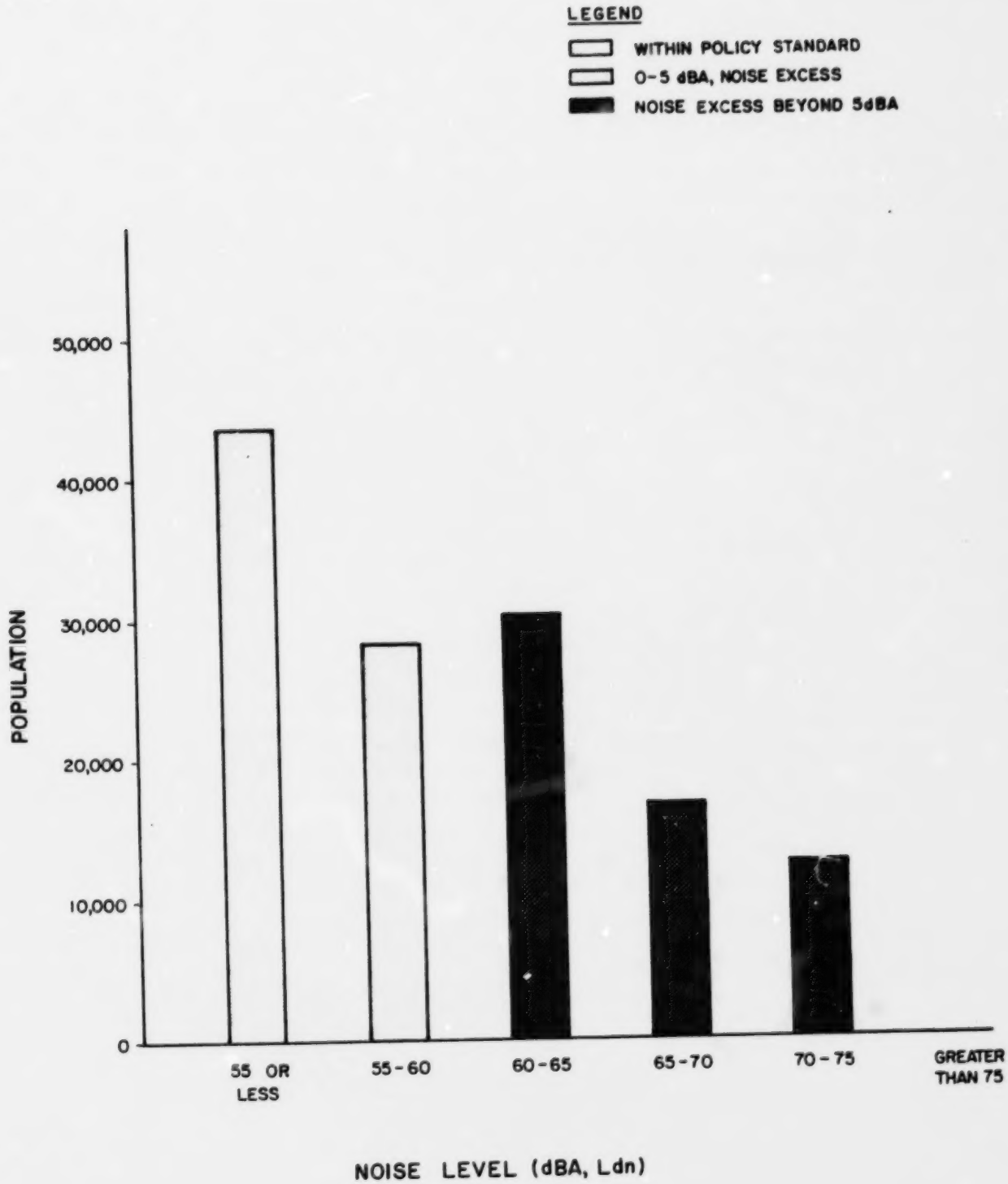
Excess noise is represented by bands of varying shades. The lightest shade represents an excess of 0 to 5 decibels. The darkest shade represents an excess of 15 to 20 decibels.

As in Figure 5.1, the bands are plotted only adjacent to residential areas and are on one or both sides of the road depending on land use.

5.5 Barrier Retrofit Program Characteristics

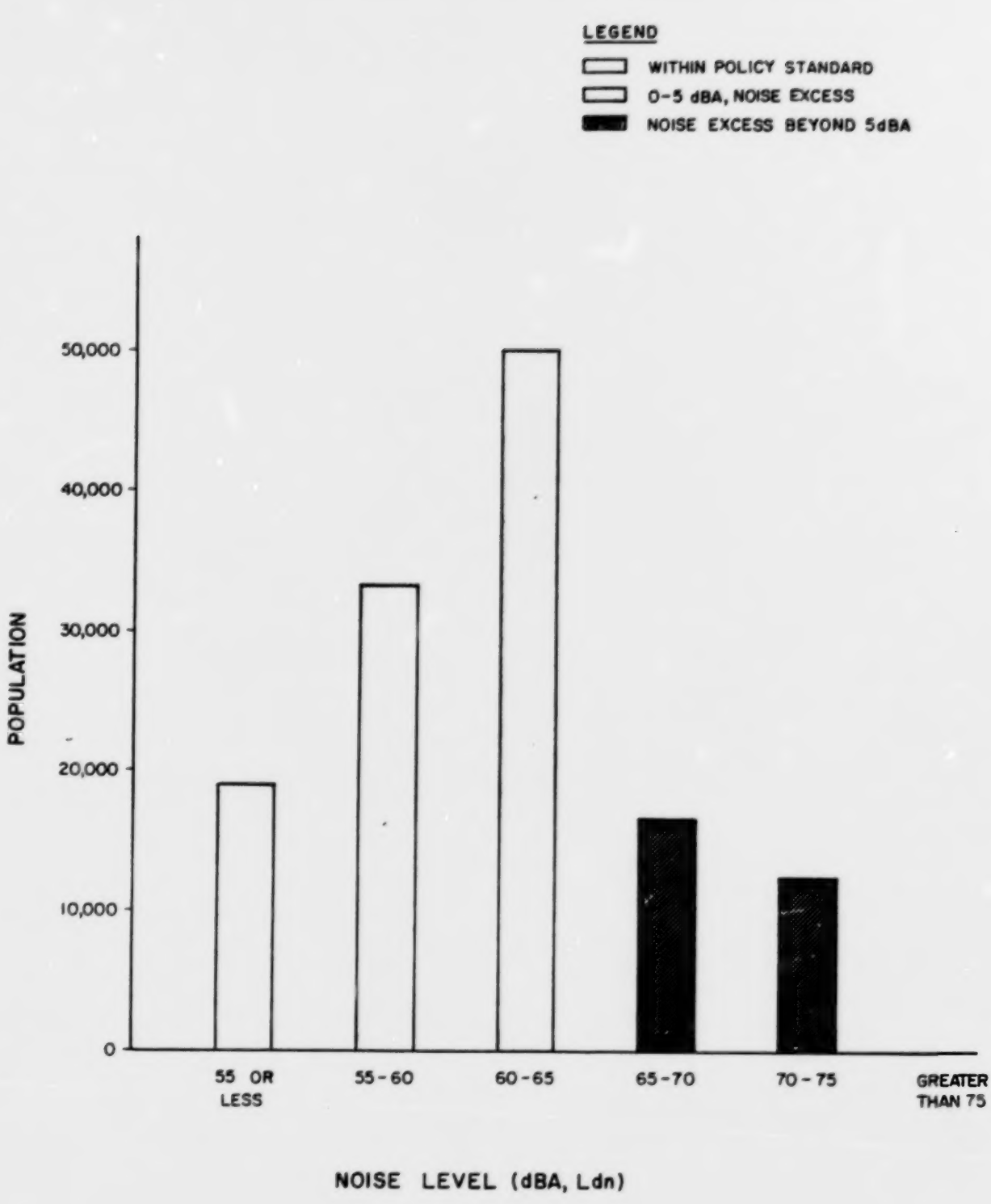
5.5.1 - Assumptions

Barrier unit costs were estimated based on discussions with manufacturers. The estimates compare with recent figures which the City of Edmonton has received in tenders for noise barriers. All costs are expressed in terms of 1980 Canadian dollars.



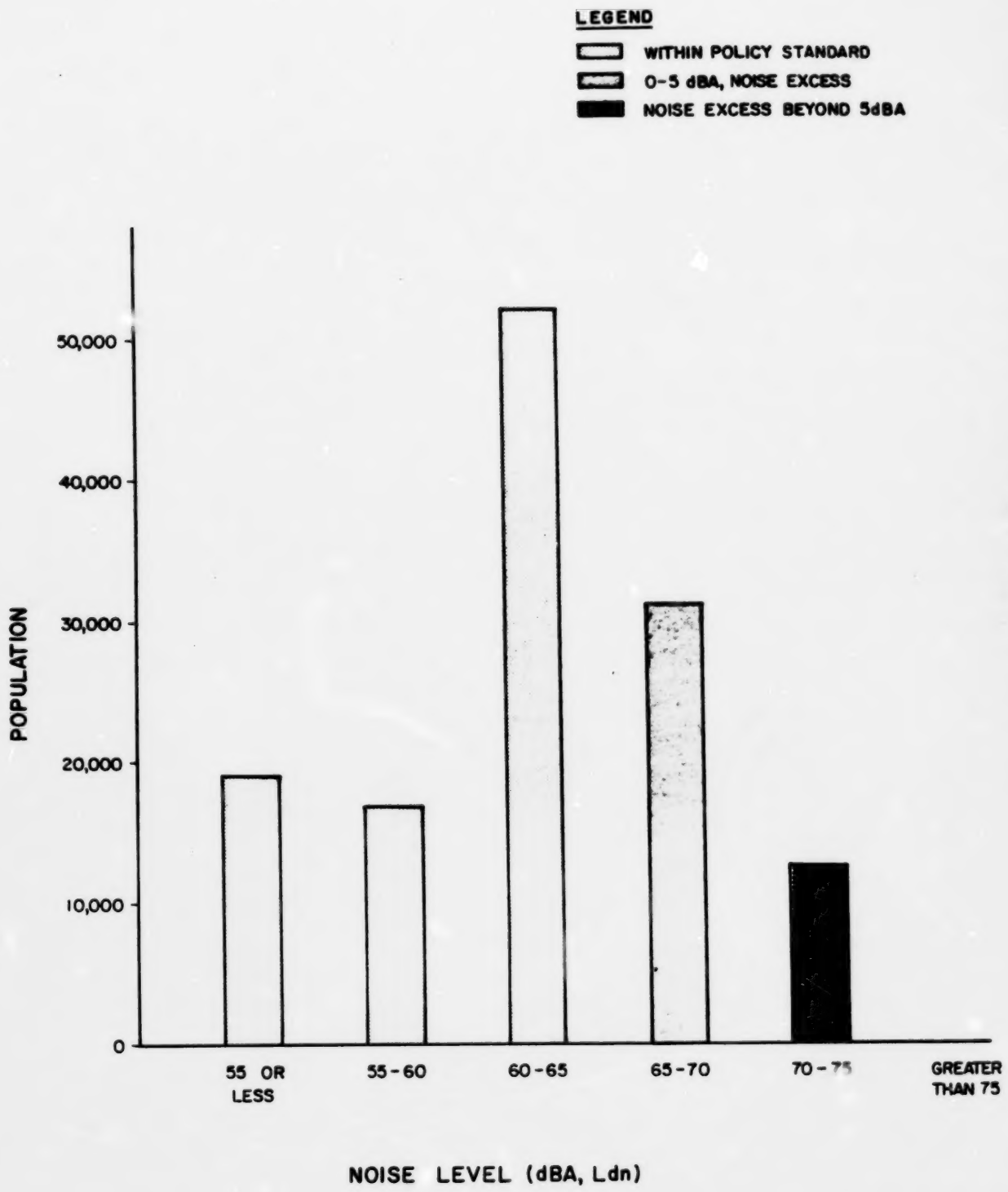
55 dBA, Ldn Policy Impacts

Fig. 5·5



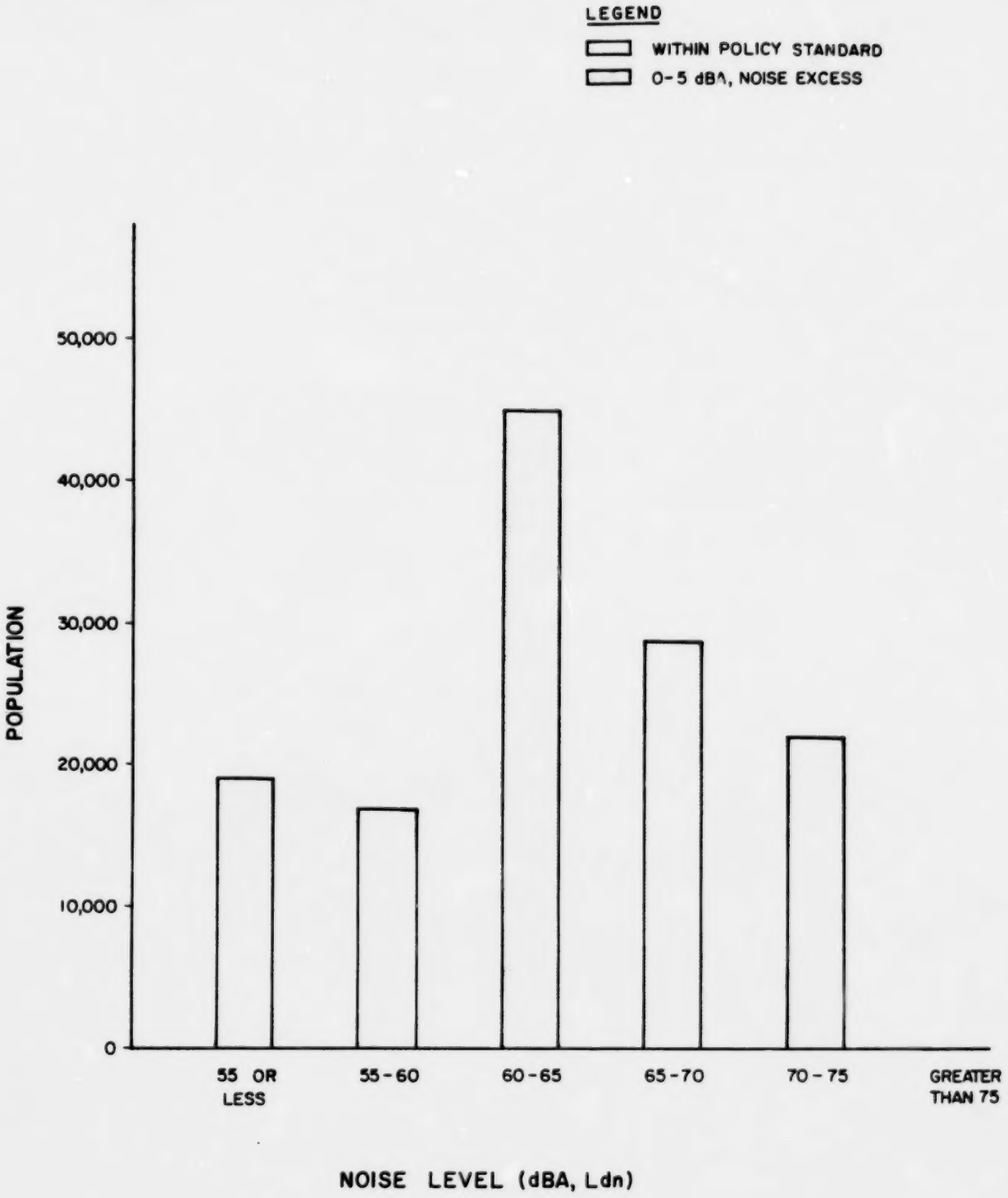
60 dBA, Ldn Policy Impacts

Fig. 5·6



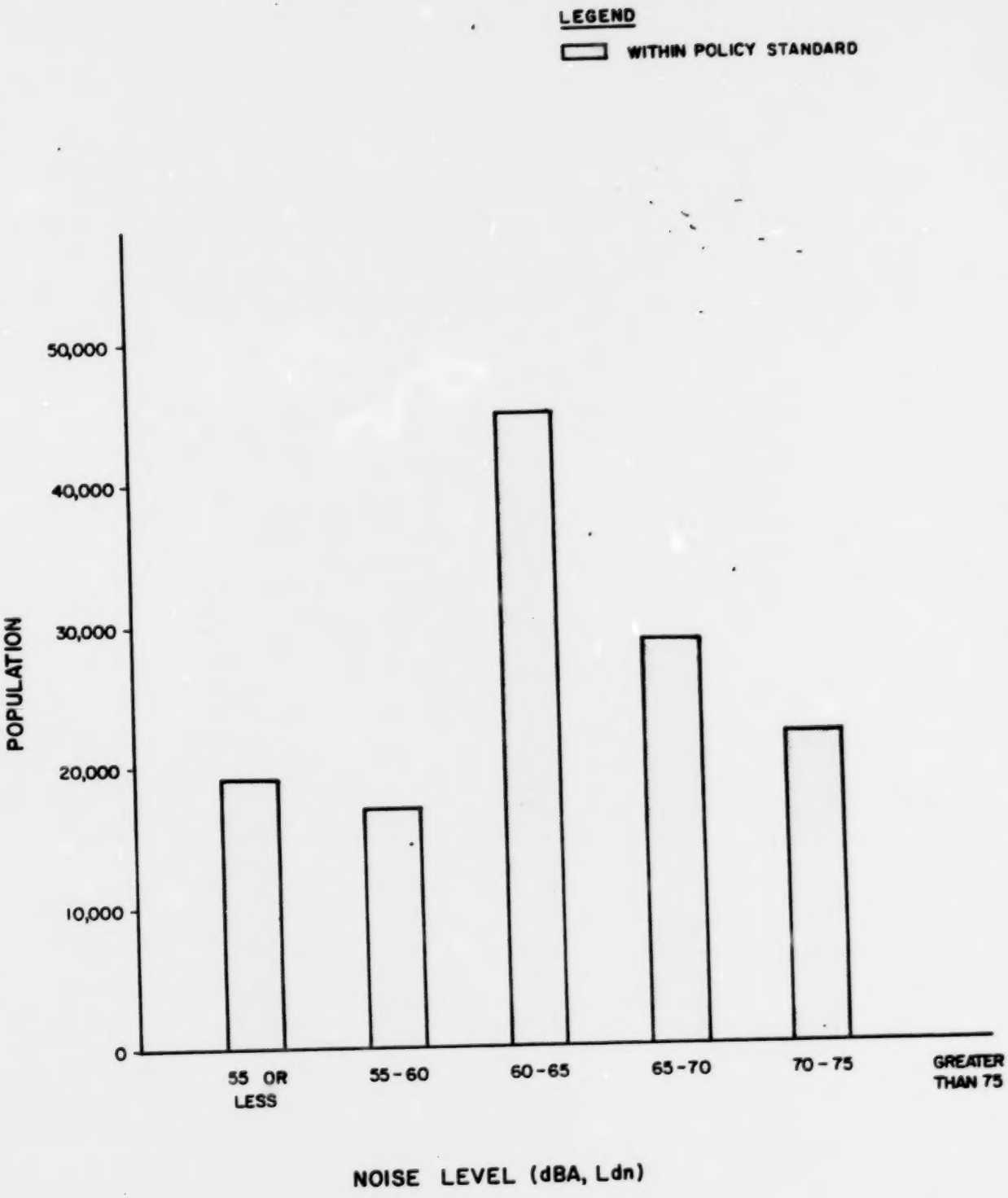
65 dBA, Ldn Policy Impacts

Fig. 5·7



70 dBA, Ldn Policy Impacts

Fig. 5·8



75 dBA, Ldn Policy Impacts

Fig. 5·9

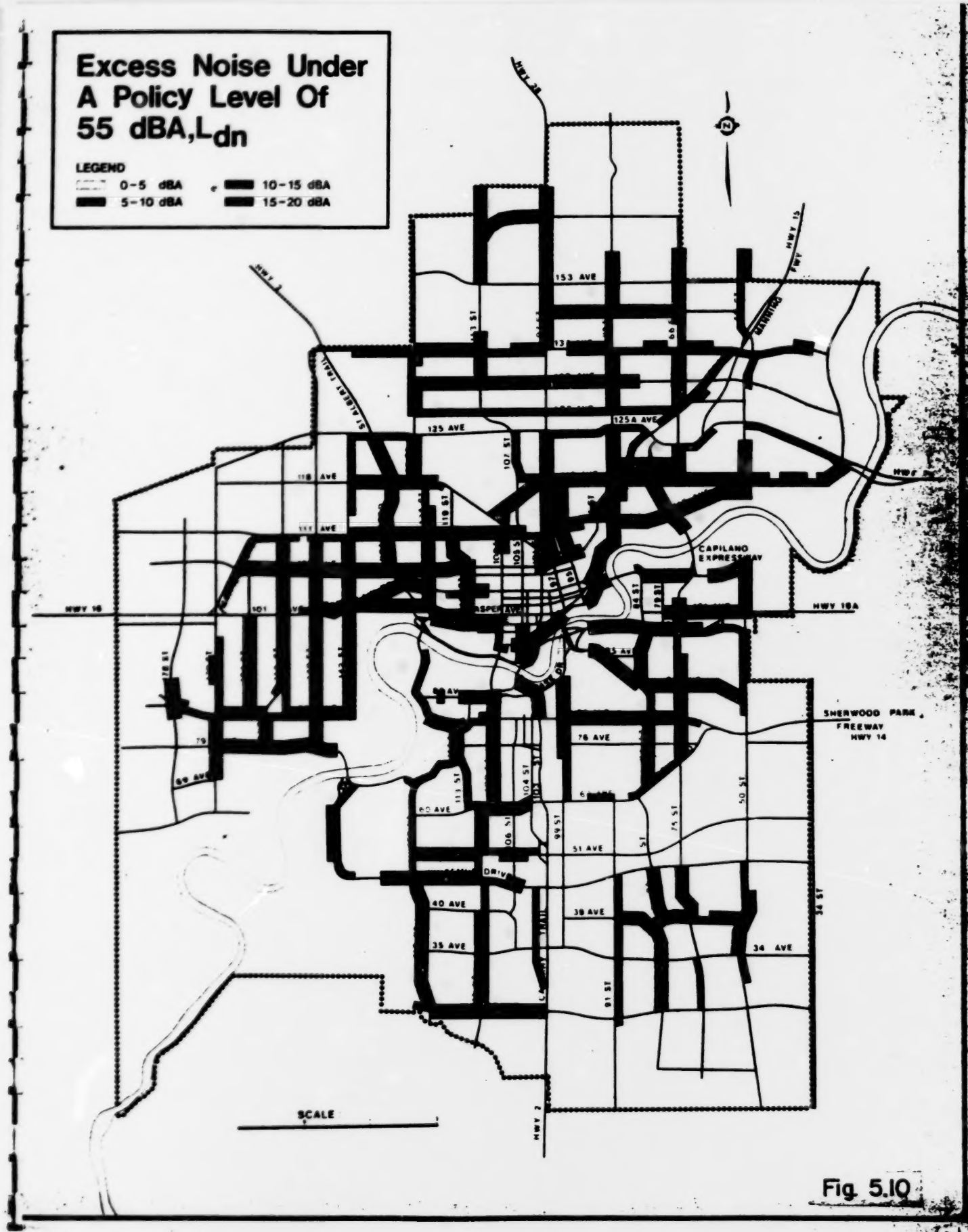
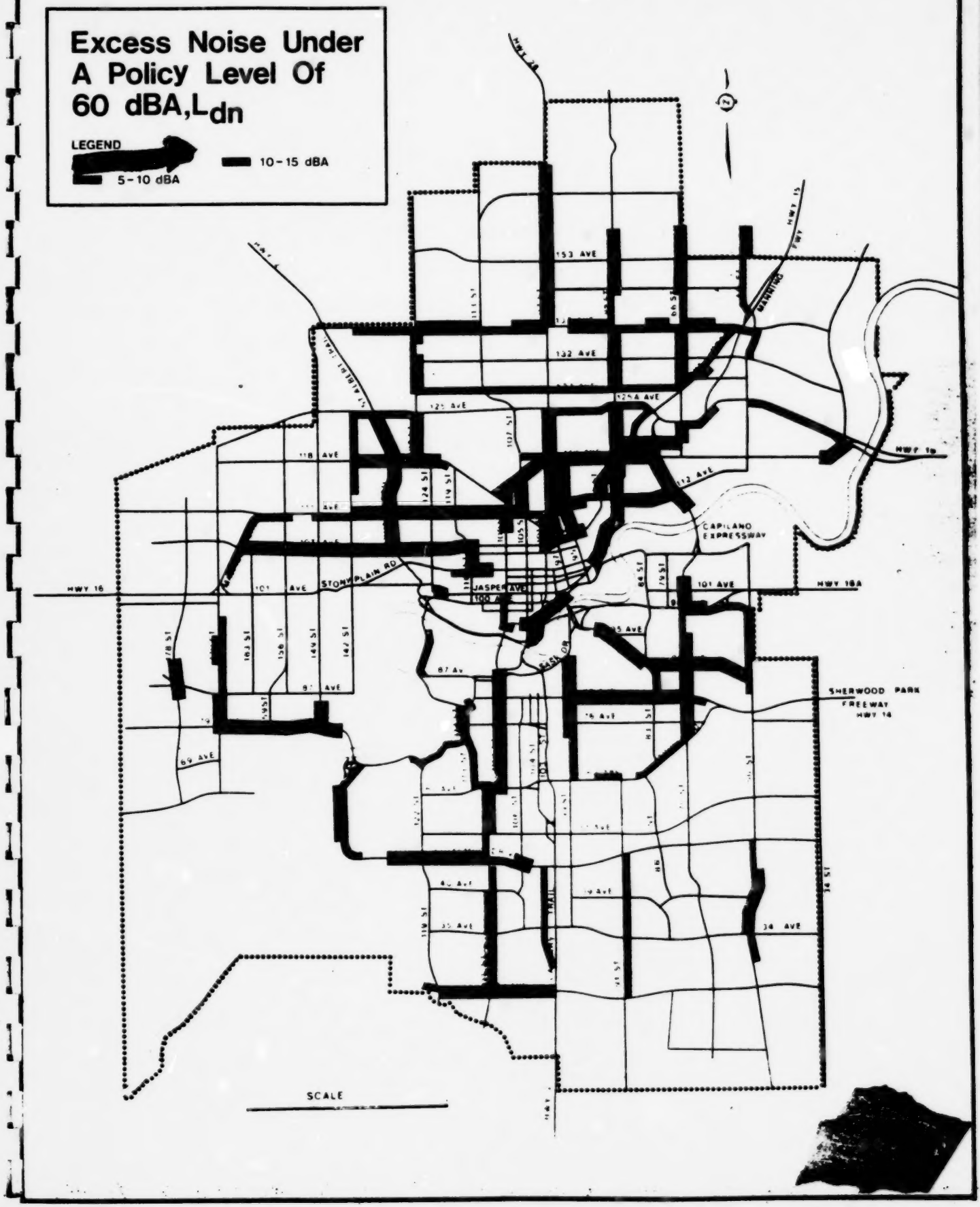

Excess Noise Under A Policy Level Of 55 dBA, L_{dn}
LEGEND
0-5 dBA
5-10 dBA
10-15 dBA
15-20 dBA
HWY 28
HWY 15
153 AVE
125 AVE
125A AVE
118 AVE
111 AVE
107 ST
118 ST
CAPILANO EXPRESSWAY
HWY 16
HWY 16A
SHERWOOD PARK FREEWAY HWY 14
76 AVE
69 AVE
60 AVE
51 AVE
40 AVE
39 AVE
35 AVE
34 AVE
34 ST
91 ST
SCALE
HWY 2

Fig. 5.10


Excess Noise Under A Policy Level Of 60 dBA, L_{dn}
LEGEND
10 - 15 dBA
5 - 10 dBA
153 AVE
132 AVE
125 AVE
118 AVE
101 AVE
87 Av
69 AVE
34 AVE
HWY 16
HWY 16A
HWY 15
STONY PLAIN RD
JASPER AVE
CAPILANO EXPRESSWAY
SHERWOOD PARK FREEWAY HWY 14
SCALE

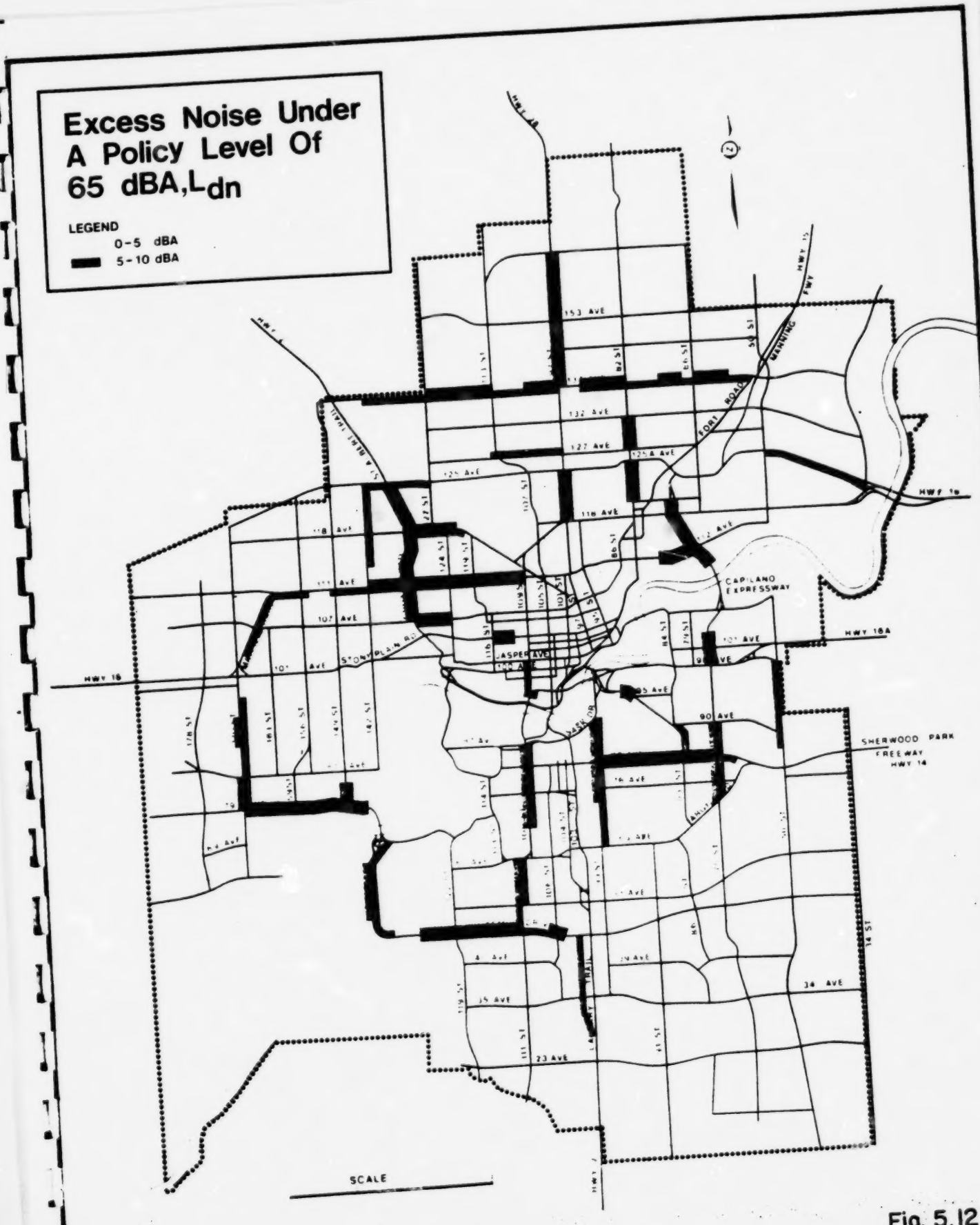

Excess Noise Under A Policy Level Of 65 dBA, L_{dn}
LEGEND
0-5 dBA
5-10 dBA
153 AVE
132 AVE
127 AVE
125A AVE
124 AVE
118 Ave
111 Ave
107 AVE
101 Ave
STONY PLAIN RD
JASPER AVE
HWY 16
HWY 16A
CAPILANO EXPRESSWAY
MANNING FWY
ANTHONY HENDAY DR
SHERWOOD PARK FREEWAY HWY 14
90 AVE
34 AVE
23 AVE
SCALE

Fig. 5.12

Excess Noise Under A Policy Level Of 70 dBA, L_{dn}

LEGEND

0-5 dBA

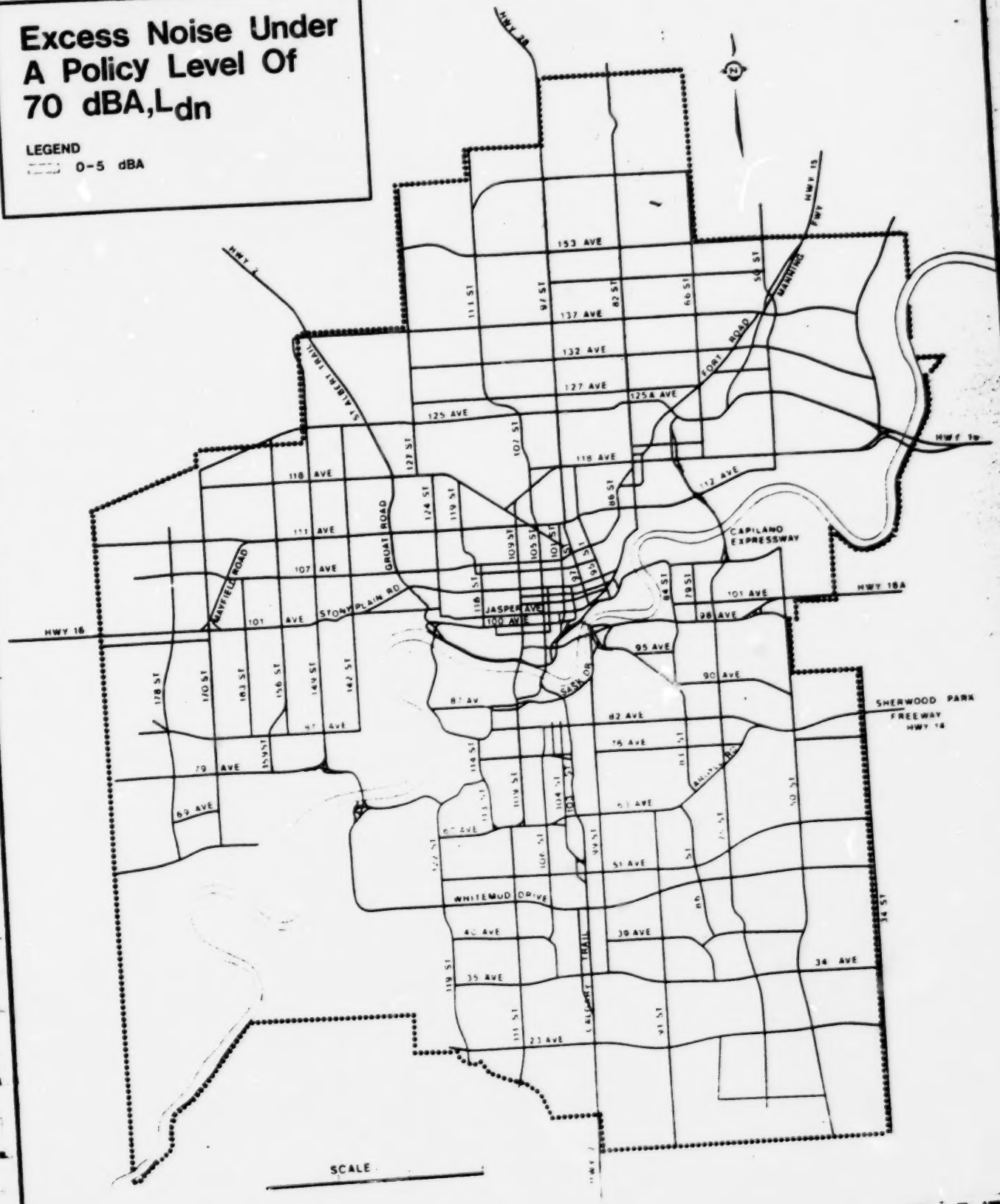


Fig. 5.13

The estimates represent average conditions. They do not allow for dealing with site specific problems, alternatives to above or below ground utilities, earthwork, landscaping, guard rails, or special treatments to the wall. Nor do the costs include the acquisition of property should it be required.

Three barrier benefits were selected as being appropriate for reducing discrete ranges of excess noise. A summary of the barrier heights, level of attenuation and unit costs are presented in Table 5.4.

Table 5.4

Summary of Barrier Assumptions

Barrier Height (metres)	Attenuation Capability (decibels)	Cost Per Metre
3	5-10	$215
4.5	10-15	$395
Greater Than 4.5	15-20	$590

5.5.2 - Summary

Barrier retrofit program characteristics for each of the alternative noise policy levels are summarized in Table 5.5. A retrofit program implemented at a design level of 55 dBA, Ldn would entail the construction of approximately 98 kilometres of barrier and would cost approximately $37 million. A retrofit program implemented at a design level of 60 dBA, Ldn would entail the construction of approximately 59 kilometres of barrier and would cost approximately $18 million. Similarly, a retrofit program implemented at a design level of 65 dBA, Ldn would entail the construction of over 27 kilometres of barrier and would cost approximately $6 million.

Table 5.5

Barrier Analysis - Summary

Height of Barrier (Metres)	Residential Density	NOISE LEVEL STANDARD (dBA, Ldn) 55 Length (kilometres)	55 Cost ($ millions)	60 Length (kilometres)	60 Cost ($ millions)	65 Length (kilometres)	65 Cost ($ millions)	70+ Length (kilometres)	70+ Cost ($ millions)
3.0	Low	32.4	7.0	26.7	5.7	24.3	5.2	0.0	0.0
	Medium	6.1	1.3	5.3	1.1	3.0	0.6	0.0	0.0
	High	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-Total		38.5	8.3	32.0	6.8	27.3	5.8	0.0	0.0
4.5	Low	26.7	10.5	24.3	9.5				
	Medium	5.3	2.1	3.0	1.2				
	High	0.0	0.0	0.0	0.0				
Sub-Total		32.0	12.6	27.3	10.8				
Greater Than 4.5	Low	24.3	14.3						
	Medium	3.0	1.8						
	High	0.0	0.0						
Sub-Total		27.3	16.1						
TOTAL		97.8	37.0	59.3	17.6	27.3	5.8	0.0	0.0

The rational for providing this information is to present a first approximation of the magnitude of both the noise attenuation requirements and the program costs at alternative design standards. It is not to suggest that such a barrier retrofit program be carried out as the sole means of noise attenuation. Other actions which may be employed include traffic management and control, building modifications, etc., and it is anticipated that such issues would be addressed within Stage II of this study.

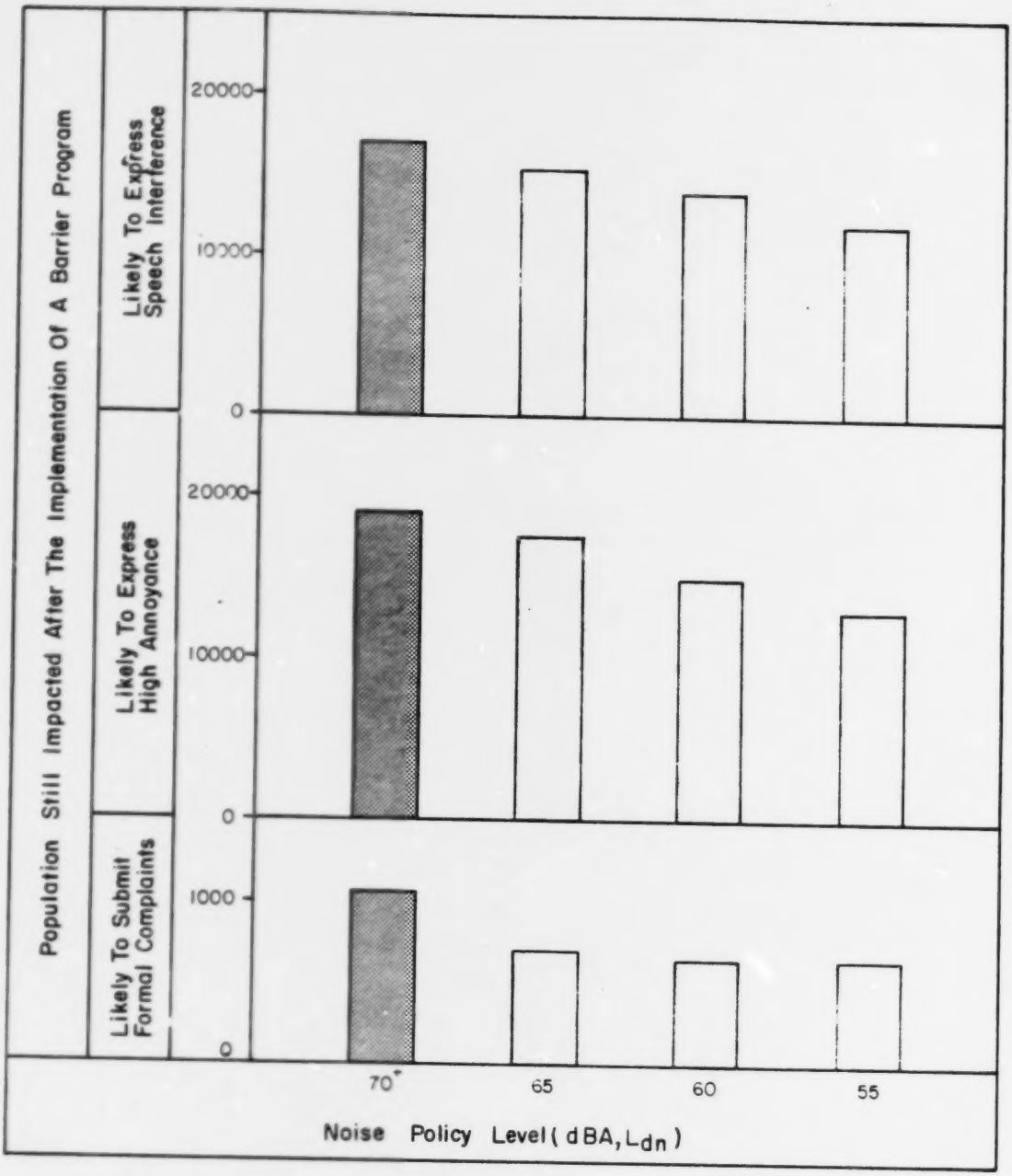
If the implementation of barriers within existing residential areas is to play a part within an overall noise retrofit program it would be necessary to establish a barrier priority scheme by which to allocate funding and to identify the locations where they should be installed and the order of priority in which they should be installed. Such priority schemes are described within Section 4.3 of this report.

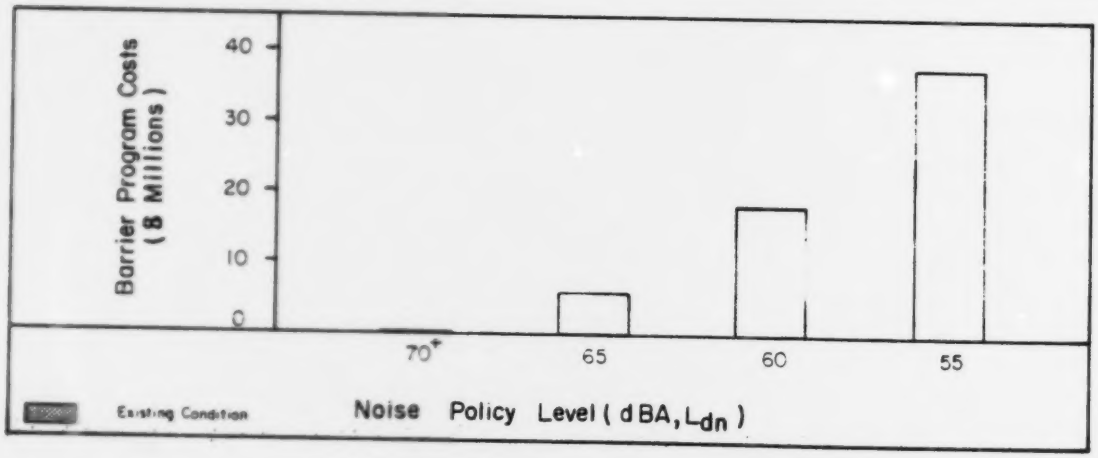
5.6 Barrier Retrofit Program Effectiveness

The significance of the social and environmental impacts for each of the five policy standards investigated was derived by applying the relationships reported in Table 2.1 of Section 2.6 to the populations presented in Table 5.3.

Two specific noise impacts are reported herein. These are interference with speech and interference with recreational activities. The two are addressed within this report because they are specifically associated with the traffic noise levels simulated by the Transportation Systems Design Department ie; outdoor noise levels at the ground storey. The results are presented in Figure 5.14.

A noise policy standard of 70 dBA, Ldn or greater represents the current or Status Quo situation. Should a survey be taken of the population residing adjacent to arterial roads, approximately 17 000 persons are likely to express interference with speech outdoors, and approximately 19 000 persons are likely to express a high degree of annoyance due to interference with social or recreational activities. Of these, it is estimated that approximately 1 100 persons are likely to submit formal complaints to the City staff.





Comparison Of Policy Impacts

Fig. 5.14

Should a barrier retrofit program be implemented for a design standard of 65 dBA, Ldn, at a cost of approximately $6 million, it is estimated that the number of persons reporting speech interference, high annoyance or submitting formal complaints would be reduced to approximately 16 000, 17 000 and 700, respectively. These figures represent reductions of six, eleven and 36 percent, respectively.

Similarly, should a barrier retrofit program be implemented for a design standard of 60 dBA, Ldn at a cost of approximately $18 million, an incremental increase of $12 million (200 percent), it is estimated that the number of persons reporting speech interference, high annoyance or submitting formal complaints would be reduced to approximately 14 000, 15 000 and 600 respectively. These figures represent incremental reductions of 13, 13 and 14 percent respectively.

Similar reductions are expected as a result of a barrier retrofit program designed at a policy standard of 55 dBA, Ldn. This is the most stringent of the policy levels examined and a barrier retrofit program implemented at this policy level would cost approximately $37 million.

Two major restrictions limit the effectiveness of a barrier retrofit program. The first is the limited benefit to be accrued for the substantial costs involved.

As previously outlined the benefits to be accrued by selecting a policy level of 65 dBA, Ldn over that of 70 dBA, Ldn are in the order of six to 36 percent reductions in negative reactions. The cost increases from zero to $6 million. Similarly, the benefits to be accrued by selecting 60 dBA, Ldn over that of 65 dBA, Ldn are in the order of 13 to 14 percent. The cost increases from $6 million to $18 million. Further marginal benefits may be gained by selecting a policy level of 55 dBA, Ldn. However the cost increases to $37 million.

The second restriction is that the effectiveness of a barrier retrofit program is generally limited to the ground storey. Such is the case in this study. The Stage I study design did not provide for the simulaton of noise or barrier heights and costs for levels above the ground storey, although in fact, barriers may occasionally be constructed high enough to provide attenuation at the second storey.

Whereas, barriers may offer an effective means for protecting both low density single storey dwellings and the ground floor of medium or high density multiple storey dwellings, in general, other means of noise attenuation are usually employed for the protection of medium and high density multiple storey dwellings. These other measures may include traffic management and control, building modification and air conditioning.

Since the Stage I study design did not provide for the simulation of noise levels above the ground storey, it was not possible to investigate associated issues such as interference with sleep, health effects and economic impacts at this time.

Policies and actions that can adequately deal with these issues can more appropriately be dealt with in Stage II of the study where such factors as traffic management and control, building modifications etc., are to be investigated.

Appendices

Appendix A

APPENDIX A - DEFINITIONS

Noise: Noise is a term used to identify sounds which are sufficiently loud or intense that they cause annoyance, interfere with speech communications, affect privacy, or interfere with either work or sleep.

Loudness: Loudness is a term used to represent the subjective magnitude of a sound, ie; the noise intensity perceived by the receiver.

Leq: Time - varying noise is usually averaged and expressed in terms of an equivalent continuous level (Leq.) which has the same annoyance value as the original sounds. The equivalent continuous noise level is commonly expressed in units of A-weighted decibels (dBA).

Ldn: Day-night sound level in dBA derived by averaging time varying sound energy over the daytime (daytime Leq) with the time varying sound energy over the nighttime (nighttime Leq) to which an additional ten decibel weighting is applied.

Lden: Day-evening-night sound level in dBA derived by averaging the daytime Leq with the evening Leq to which an additional five decibel weighting is applied and with the nighttime Leq to which an additional ten decibel weighting is applied.

Ln: Sound levels in dBA which are exceeded for a percent of the time. Examples;

L5 - Sound level exceeded five percent of the time.
L10 - Sound level exceeded ten percent of the time.
L50 - Sound level exceeded fifty percent of the time.

L_{max}: Maximum noise level recorded during a defined period of time and commonly expressed in units of A-weighted decibels (dBA).

dBA: Noise measured using sound level meters is transformed electronically to approximate noise levels as heard by the human ear. Noise measurements transformed in this manner are commonly expressed in units of A-weighted decibels (dBA).

Daytime: Arbitrarily selected period of interest. Alternatives often employed include;

- 7 a.m. - 6 p.m. (11 hours)
- 7 a.m. -10 p.m. (15 hours)
- 7 a.m. -11 p.m. (16 hours)

Evening: Arbitrarily selected period of interest. Duration often selected for use;

- 6 p.m. -10 p.m. (4 hours)

Nighttime: Arbitrarily selected period of interest. Alternatives often employed include;

- 10 p.m. - 7 a.m. (9 hours)
- 11 p.m. - 7 a.m. (8 hours)

Appendix B

APPENDIX B - BARRIER CASE STUDIES; An Annotated Bibliography

B.1 Interstate Route 75 - Troy City, Michigan

(Reference: Van Buseck, C.R., Measurements of Reduced Traffic Noise Annoyance Obtained With An Earth Berm, Noise-Con Proceedings, 1977)

Reason For Effecting Noise Mitigation

Citizen complaints about highway noise to City officials through organized community action including submission of a signed petition.

Source of Noise

Interstate Route 75 - a limited access divided highway with a speed limit of 55 miles per hour. The average daily traffic volume in 1975 was reported to be 59 000 vehicles per day, of which approximately 20 percent represented truck traffic.

Sound Level Before Introducing Noise Mitigation

Dwellings nearest the road, 80 metres from the centre of the nearest lane, were exposed to noise of approximately 67 dBA, Leq (24 hours).

Design Criteria

Not specifically mentioned.

Barrier Description

An earth berm 610 metres long and 3.7 metres high relative to the shoulder of the road.

Attenuated Sound Levels

The berm reduced sound levels by approximately 6 decibels to 61 dBA Leq.

Cost and Financing

Total cost was $41 700 (approximately $70 per metre) and was financed by the homeowners themselves through special assessment levied by the Municipal tax assessment office. Cost sharing among the individual homeowners was determined on the basis of the number of rows away from the highway.

Results of Social Surveys

Approximately 60 households were interviewed before and after the berm was constructed. Perceived benefits of noise reduction were expressed by residents of the first 2 rows of houses within 135 metres of the berm. Within that area most residents experienced serious annoyance before the construction of the berm and were quite willing to pay for noise mitigation. After the construction of the berm these same persons reported decreased annoyance and that the change was considered cost - beneficial. Homeowners in the first row reported receiving the greatest benefits from the berm and thus were willing to pay a maximum dollar value ranging from $145 per dBA to $235 per dBA for the berm and all of its benefits.

Case Study Conclusions

The study demonstrated that where traffic noise exceeds acceptable levels people are willing to pay for noise reduction. In this case, an Leq of approximately 60 dBA appeared to be the threshold for unacceptable noise and willingness to pay. The perceived appreciation of house resale value due to the construction of the berm averaged approximately $650 per dwelling unit (house prices ranged from $60 000 to $70 000 dollars prior to construction of the berm).

B.2 The Youngmann Expressway, Buffalo, New York

(Reference: Cohn L.F., A Case Study in Highway Noise Retrofit, Inter-Noise Proceedings, 1978).

Reason for Effecting Noise Mitigation

Extensive citizen complaints to the New York State Department of Transportation.

Source of Noise

The Youngmann Expressway - section of roadway located between State Route 5 and State Route 324 in suburban Buffalo, Town of Amherst.

Sound Levels Before Introducing Noise Mitigation

Sound levels measured in the backyards of the first and second rows of dwelling units were 75 and 65 dBA (L10) respectively.

Design Criteria

Sound levels were compared against the maximum levels specified by the FHWA, 70 dBA (L10) and a goal was set for a 10 dBA reduction in noise at the first row of homes.

Barrier Description

The barrier is to be constructed in the spring of 1980. It is expected that the final barrier will be 12 to 16 feet high above the pavement, and approximately 3500 feet long.

Attenuated Sound Levels

Attenuated sound levels are not currently available.

Cost and Financing

The estimated cost of the barrier in 1978 was approximately $400 000 ($375 per metre) of which 90% would be eligible for funding under the FHWA Noise Abatement Program, and the balance of which would be paid for by the state of New York.

Results of Social Surveys

Not available until the barrier is completed.

B.3 Interstate Route 35-W, South Minneapolis, Minnesota

(Reference: Lambert R.F., Experimental Evaluation of a Freeway Noise Barrier, Noise Control Engineering, September-October 1978.)

Reason For Effecting Noise Mitigation

A pilot program to evaluate barrier effectiveness.

Source of Noise

A section of Interstate Route 35-W in South Minneapolis. The traffic volume was reported to be over 100 000 vehicles per day of which approximately six percent was attributed to trucks.

Sound Level Before Introducing Noise Mitigation

Noise levels at the first row of homes, approximately 75 metres from the road centre line, were measured to be in excess of 65 dBA Leq daytime and 57 dBA Leq night time. At some locations the Leq values were 5 dBA higher due to topographical variations.

Design Criteria

Reduction of the L10 noise level by at least 10 dBA at the first row of homes.

Barrier Description

A combination of earth berm and wall with a total length of approximately 540 metres. The wall itself ranges from 1.6 to 5.8 metres in height and is constructed of timber boards mounted on timber posts.

Attenuated Sound Levels

The average reduction in sound level at the first row of homes was approximately 8 decibels, and at the second row approximately 5 decibels.

Cost and Financing

The actual contractual cost of the barrier plus landscaping was $376 200 (approximately $700 dollars per metre). The barrier was financed by both the Federal Highway Administration and the State.

Results of Social Surveys

Reduction in annoyance at the first row, by the barrier, was reported to be equivalent to moving the row one block further from the centre of the roadway (an actual reduction in the mean annoyance of about two full scale points on a 6-point scale). At the second row, the mean annoyance reduction was reported to be one scale point. The responses indicated that on the average, the barrier was performing its intended function of reducing annoyance. All of the comparison data indicated that the annoyance levels leveled off at the third row of homes located a distance in excess of 150 metres from the highway centre line.

Case Study Conclusions

The public's reaction is mixed. In general, residents protected by the barrier were satisfied. Others who did not benefit directly, criticized the high initial cost and aesthetics.

B.4 Highway 401, Metropolitan Toronto, Ontario

(Reference: Ontario Ministry of Transportation and Communications, Privacy Fence Evaluation - Highway 401 (Warden Avenue to Victoria Park), August 1976.)

Reason For Effecting Noise Mitigation

A demonstration project aimed at providing screening on major freeways in response to complaints from residents.

Source of Noise

Highway No. 401 between Warden Avenue and Victoria Park comprising 14 lanes with controlled access operating at 70 m.p.h. (since reduced to 100 km/hr or 60 m.p.h.).

Sound Level Before Introducing Noise Mitigation

Not specified.

Design Criteria

It was decided that a solid fence be constructed to a height of 8 to 10 feet based on previous experience in the Metropolitan Toronto Area.

Barrier Description

Zinc coated steel panels mounted on steel posts to heights of 8 and 10 feet. The barrier length is approximately 13 000 feet.

Attenuated Sound Levels

The sound levels before and after the construction of the barrier are not available. However, the reported reduction in noise levels were approximately 5 to 9 decibels in the backyards of houses immediately adjacent to the highway.

Cost and Financing

The estimated 1975 cost of the barrier per linear foot was approximately $40 for the 10 foot high section, while the cost for the 8 foot section was approximately $22.

Results of Social Surveys

Noise was a very serious annoyance prior to the installation of the fence. The average reduction of 5 dBA did not result in tolerable levels. The privacy fence was more effective in dealing with other annoyances associated with urban highways. Fumes, dust and dirt, and apprehension of vehicles leaving the roadway were indicated by local residents to be only minor problems after construction of the privacy fence. Residents also indicated that salt spray, privacy, weeds and litter, headlight glare and destructive acts by transients had been reduced to satisfactory levels.

Case Study Conclusions

The privacy fence was effective in reducing minor annoyances. Although it did not reduce noise significantly, the results were encouraging and the report recommended that specifically designed noise barriers should be re-evaluated.

B.5 Highway 401, Metropolitan Toronto, Ontario

(Reference: Environics Research Group Limited, Etobicoke, Freeway Noise-Social Impact Survey, Phase 1, January 1977.)

Reason For Effecting Noise Mitigation

As a result of the noise complaints received by the Government of Ontario and the announcement of a noise barrier retrofit policy, a priority program was established to deal with such complaints.

Source of Noise

Highway No. 401 between Dixon Road and Kipling Avenue comprising 14 lanes with controlled access operating at 100 km/hr.

Sound Levels Before Introducing Noise Mitigation

Sound measurements taken within the study area ranged from 70 to 80 dBA, Leq.

Design Criteria

The barrier was subject to the established barrier retrofit program, with a maximum allowable height of approximately 14 feet.

Barrier Description

Steel barrier constructed to a height of 13'-4" extending approximately 3000 feet.

Attenuated Sound Levels

The sound levels measured in backyards behind the barrier ranged from 68 to 73 dBA, Leq. The average reduction in sound level was approximately 7 dBA.

Cost and Financing

The cost of the barrier including supply and installation was approximately $40 per linear foot. The barrier was financed by the Province of Ontario.

Results of Social Surveys

Residents reported a significant decrease in annoyance due to freeway noise, interference with conversation, interference with relaxation,

litter from freeway traffic, winter salt spray, and increased satisfaction with visual privacy. Increased satisfaction was most prominent in households immediately adjacent to the freeway where dissatisfaction was highest before the introduction of the noise barrier. In terms of absolute levels, dissatisfaction with freeway noise remained high within the experimental area. Almost half the households in the area reported dissatisfaction with freeway noise after the construction of the noise barrier.

Case Study Conclusions

The barrier is successful in reducing many annoyances associated with the freeway. The perceived effectiveness of the barrier varies according to the distance one lives from it.

B.6 Queensway, Ottawa, Ontario

(Reference: Environics Research Group Limited, Analysis of Noise Barrier Impact on Dissatisfaction with Freeway Annoyances, Ontario Ministry of Transportation and Communications, April 1979).

Reason for Effecting Noise Mitigation

In response to citizens complaints and to comply with the retrofit policy of the Government of Ontario.

Source of Noise

Queensway between Melrose Avenue and Loretta Avenue.

Sound Level Before Introducing Noise Mitigation

Not specified.

Design Criteria

The height of the barrier was designed to eliminate a direct line of sight and to provide meaningful noise reduction.

Barrier Description

A wooden beam barrier, 10 feet in height and extending in length for 2000 feet.

Attenuated Sound Levels

Measurements before and after the construction of the noise barrier were not reported, however, the average attenuation was approximately 6 dBA.

Cost and Financing

The cost of the barrier including installation was approximately $54 per linear foot. The project was financed completely by the Province of Ontario.

Results of Social Surveys

As a result of the construction of the noise barrier, residents reported a significant decrease in dissatisfaction with freeway noise annoyance, sleep disturbance, noise levels, litter, winter salt spray, fumes, and increased visual privacy from passing vehicles. With the exception of vibration, a significant reduction in dissatisfaction with all types of freeway annoyances was observed. Households living closest to the freewy where dissatisfaction was greatest before the introduction of the noise barrier reported receiving the most significant benefits. Approximately 20 percent of households remained dissatisfied with any particular annoyances after the noise barrier was built.

Case Study Conclusions

The barrier effectively reduced many annoyances including those resulting from dust and dirt, and freeway traffic noise. Unlike the case study reported previously, where up to 50 percent of the respondents within the study area remained dissatisfied with a freeway annoyance after the construction of the barrier, only 33 percent remained dissatisfied in the Ottawa experimental area. The authors attribute this result to the fact that the sound levels emanating from Highway No. 401 are generally much higher than those emanating from the Queensway (approximately 12 dBA difference).

B.7 Noise Barrier Case Study in the United Kingdom

(References: Scholes, W.E., The Physical and Subjective Evaluation of Roadside Barriers, U.K. Building Research Establishment, Inter-Noise Proceedings, 1977.)

Reason For Effecting Noise Mitigation

An experimental study to evaluate the benefits derived by replacing an ordinary highway privacy fence with a permanent noise barrier.

Source of Noise

An unnamed elevated motorway in the United Kingdom located approximately 25 metres from an existing residential area.

Sound Level Before Introducing Noise Mitigation

Not reported, although it is concluded that the levels may have exceeded the acceptable criterion in the U.K. of 70 dBA, (L10).

Design Criteria

Not reported in the study, however, the objective of the study was to replace an existing privacy fence with a more effective sound barrier.

Barrier Description

The privacy fence consisted of a visually opaque thin wooden fence. Details of the new noise barrier are not reported, however, it is implied that the new barrier is solid, continuous, and effectively interrupts the direct line of sight.

Attenuated Sound Levels

The noise barrier provided a reduction of four to eight dBA depending on measurement position.

Cost and Financing

No figures were made available. However, the cost of the retrofit was borne by the Government in accordance with the Land Compensation Act.

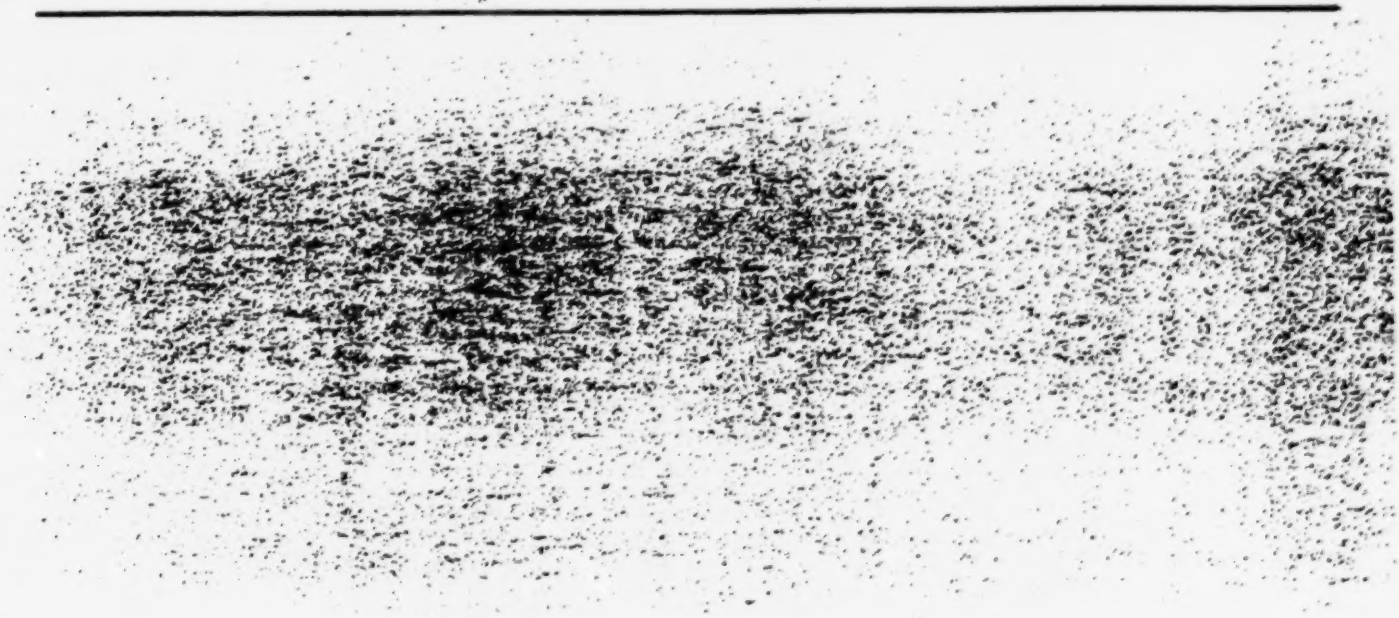
Results of Social Surveys

Dissatisfaction was rated on a nine point scale. Construction of the barrier reduced dissatisfaction from 6.8 to 5.5. In general, residents reported that conditions had been improved by the additional noise attenuation. There was some criticism of the visual impact, and it was thought that some shrubs would have helped to soften the hard outline of the barrier. About 10 percent of the sample population preferred the view of the traffic over that of a noise barrier.

Case Study Conclusions

The replacement of the acoustically ineffective opaque wooden fence by the purpose-built noise barrier, was appreciated by the local population.

Appendix C



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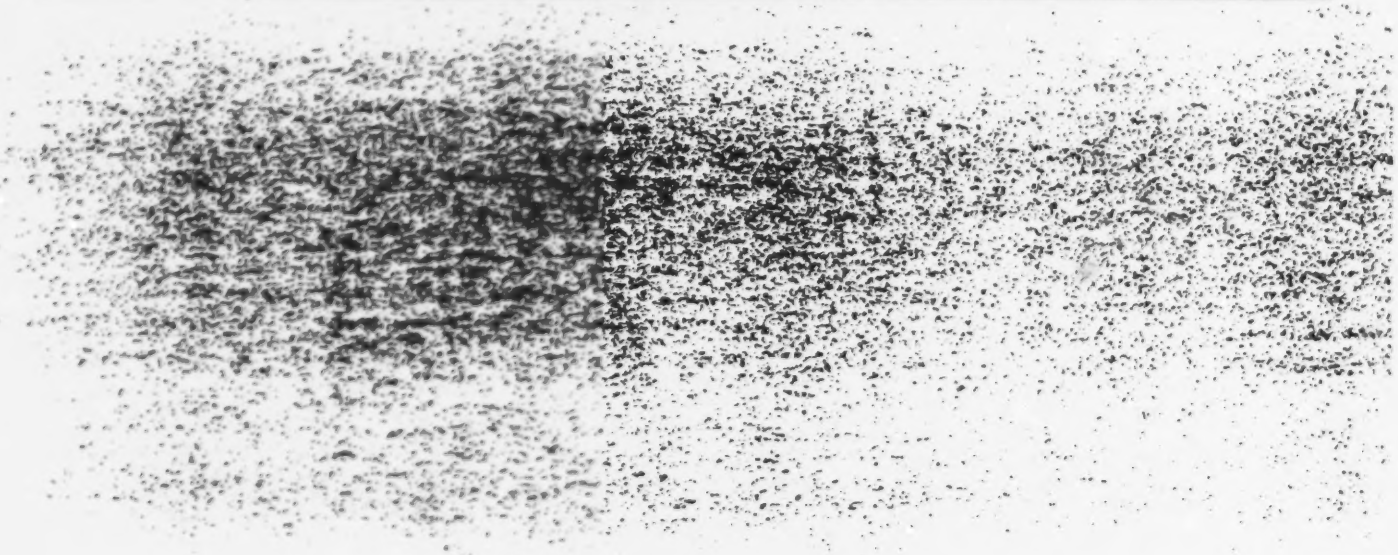
Appendix D



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HEALTH EFFECTS OF TRAFFIC NOISE

A LITERATURE REVIEW

This report was prepared as a contribution to the City of Edmonton Urban Traffic Noise Policy Study, May 1980. Papers obtained by a computer search of the Medline data bank were reviewed by a working group consisting of Dr. J. M. Howell, Medical Officer of Health, Dr. J. C. Gillespie, Deputy Medical Officer of Health, Dr. L. V. Jonat, Deputy Medical Officer of Health, Dr. K. Pennifold, Director of Environmental Health and Dr. D. Phillips, Director of Mental Health. The work was coordinated and summarized by D. Thomson, Public Health Inspector/Health Educator. Mrs. Trudie Gelineau transcribed the text. The report was approved by the Local Board of Health at its 1980 05 07 meeting.

INTRODUCTION

No one doubts that man is annoyed, awakened, disturbed and frustrated by noise intrusion, that communication with his fellow man may be disrupted and his performance capability decreased.[7] When he is exposed to moderate or loud noise over long periods of time his hearing may be temporarily or permanently damaged and at lower levels he may experience physiological, sociological, and behavioural effects. Nevertheless, considerable mystery remains concerning the subtle, long-term effects on man of noise in the environment.[9]

The subject has been much debated[27] but insufficiently researched. Among those who have reviewed the matter, there is consensus on the need for standards[7,20,35] and a reasonable agreement that the proposed limits of the International Standards Organization and the U.S. Environmental Protection Agency offer a reasonable safeguard from noise-induced effects to society in general. In other words, the standards are compatible with the protection of public health and welfare for most people while engaged in most activities in most locations. Because of inherent biological variation it is impossible to equate noise levels with precise effects in man.

The effects of traffic noise on health are diverse, invoking psychological as well as physiological responses. The term "health" is used here in the sense defined by the World Health Organization and subsequently modified by Milton Terris to read:

> *a state of physical, mental and social well-being and ability to function and not merely the absence of illness and infirmity.*

This paper, therefore, includes consideration of some psychological and social effects of noise that tend to contribute to ill-health.

The definition of noise as "unwanted sound" implies that complaints and annoyance will occur when it intrudes into privacy. Of all the different noise sources, traffic noise seems to be the most annoying and objectionable.[2,23] This annoyance factor is measurable and most meaningful when considering protection levels for community.[27]

PHYSICAL HEALTH EFFECTS OF TRAFFIC NOISE

Hearing loss, permanent or temporary, is the most overt effect of noise. Although unlikely to occur due to traffic noise except with prolonged exposure, the possible mechanisms of its production are of interest.

Even the most intense noise fails to damage the relatively unimportant outer ear.

Rarely, the eardrum can be ruptured or the middle ear ossicles dislocated by intense noise (140 dB) or blast. However, the primary site of auditory

injury is the receptor organ of the inner ear, called the Organ of Corti, the integrity of which is vital to normal hearing. Excessive response to noise destroys the hair cells and other parts of the organ. The sensitivity is greater for sounds of higher frequency and regeneration does not occur.

Temporary threshold shift, that is, a change in the ability to detect sounds of particular frequencies, occurs with exposures to 60-80 dBA for 8-24 hours. People differ in their vulnerability to noises of different pitches. For instance, women are less sensitive to low frequencies and more sensitive to high frequencies. Recovery is rapid when the threshold shift is small (< 40 dB) and duration of exposure short (< 8 h).

In assessing the significance of permanent hearing damage, the thresholds for tones in the region most important for speech (500, 1000 and 2000 Hz) are neglected, even though they may be important in some occupations.[27]

The U.S. Environmental Protection Agency concluded that permanent hearing damage can occur after 40 years where there is a daily exposure to these levels of sound as determined by the Leq (loudness equivalent unit) measure*:

75 dBA for 8 hours per day, or
78 dBA for 4 hours per day, or
81 dBA for 2 hours per day, or
84 dBA for 1 hour per day. [21]

These noise levels can be produced by traffic noise, although more likely sources of these levels of noise are high-noise vocations (e.g. heavy construction) or leisure activities (e.g. rock music). A continuous exposure to 55 dB for 40 years may produce some hearing loss.[9]

The non-auditory effects on health include physiological disturbances involving the cardiovascular and nervous systems and various types of stress reaction. Road traffic noise can lead to distinct temporary changes in blood levels of sugar, uric acid, total lipids, cholesterol, and triglycerides, the effect becoming more marked with louder noise of longer duration. The significance of these biochemical changes has not been established. Noise has a definite effect on blood pressure levels.[1,3,15] Swedish students in a school near a busy thoroughfare had blood pressure levels averaging 131/82 as opposed to 120/68 for children in a school on a quiet street. Vaso-constriction of the fingertips and temples is a common response to noise.[13,20]

These physical changes detectable in the presence of noise indicate that noise is a source of stress. A stressor has been defined as a demand made by the internal or external environment of an organism that upsets homeostasis. Reviewing various studies of the effects of different stressors, Dunn[2] reported that "noise itself has been shown to be a more serious stressor than arterial incision, moderate adrenaline injection, or hemorrhage in laboratory study." According to Glass and Singer[11] unpredictable,

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*Leq = an averaging of sound pressure level (not an arithmetic average) over a set time period - up to 24 hours. For example, $Leq_{(8)}$ = loudness equivalent measure for eight hours of continuous noise.

uncontrollable events are more stressful than controllable and predictable situations. Aperiodicity and uncontrollability are of course common characteristics of most traffic noise situations.

Task performance in noisy environments has been studied. While changes in performance occur, they vary widely among different test subjects.[4,22] Steady noises do not appear to interfere with human performance until about 90 dBA, but irregular bursts below this level may have an effect. It appears that higher frequencies are more important. Noise reduces the accuracy more than the quantity of work. Complex tasks are more likely to be adversely affected than simple tasks.[11,27] In some circumstances, individuals of high intelligence do less well while low intelligence subjects may experience improved performance.

Traffic noise may interfere with sleep: the effect is insidious. Volunteer studies using physiological monitoring have shown that subjects introduced to a noisy environment soon overcome their inability to sleep but the quality of the sleep is not identical with that in the pre-noise period.[36] Therefore a questions remains about possible long-term effects.

Griefahn and Muzet[12] offer the following model of the progressive effects of noise-induced sleep loss as the means by which health is impaired over time.

> *1. Exceeding a certain level of intensity (and depending on physical and personal factors), nightly occurring noises lead to a reduction of Delta sleep* and perhaps of the total sleep time. During the first time of exposure, habituation begins to take place (though, again, this depends on physical and personal factors). However, small sleep deficits can be recorded even after years.*
>
> *2. Concerning psychic and psychomotoric performance, sleep disturbances are compensable during the first time of exposure.*
>
> *3. Sleep deficits accumulate with persisting disturbances. After a certain point, however, sleep deficits can no longer be compensated for and a diminution of performance occurs.*
>
> *4. In conjunction with a decrease of performance, these deficits lead gradually to functional diseases.*
>
> *5. If noise exposure remains morphologically defined, diseases which may be irreversible and progressive can be expected.*

The probability of a given level of noise causing a shift to a shallower and therefore presumably less desirable level of sleep can be calculated from the experimental studies. For levels of 40-45 dBA it is about 15%.[19] However, there is considerable individual variation. In general, women are more easily disturbed than men and persons over 60 years are more susceptible. Sleep disturbance may have a special impact on children in the 4-6 year age group, on the sick and on persons with personality disorders.[2,12,16,24]

---

*Delta sleep is the deepest of the four stages of sleep as described by Miller.[18]

In attempting to determine tolerable noise levels, a major consideration is its propensity to interfere with speech communication. It has been found necessary to allow for 100% sentence intelligibility indoors, 95% outdoors (Appendix 1). By these standards, speech interference occurs at relatively low levels, 55 dBA outdoors and 40-45 dBA indoors.[26,30] Levels around 70 dB increase the difficulty of speech communication and may lead to more profound effects. For instance, children whose only play area is continuously noisy may have their language development impeded because of limited opportunities for verbal communication.[19]

Speech interference in domestic neighbourhoods has contributed to an increasing amount of time spent indoors. As the U.S. National Bureau of Standards[34] reported in 1971:

> *In an increasing number of instances, it is no longer possible to engage in conversation at a normal voice level on one's patio because of noise intrusions; therefore the family will tend to spend more time indoors. It might even be speculated that, taken as a whole, these tendencies are divisive in nature and contribute to make the existing problems in our society even worse. This occurs because they tend to separate and isolate individuals and families in contrast to an expansion of interest and activities usually equated with healthy living.*

In addition to speech interference, noise brings the added danger of masking audible signals[21] such as crying children, telephone and door bells, warning sounds, etc. Temporary threshold shift induced by noise may have the same effect.

PSYCHOLOGICAL AND SOCIAL EFFECTS OF TRAFFIC NOISE

Traffic is rated as the most annoying environmental noise,[23] tending to bother people a great deal more than the same volume of continuous or regular noise. Nausea, headaches, instability, argumentativeness, sexual impotency, changes in general mood, anxiety and other effects have been associated with exposure to noise but all are difficult to assess.[19]

Population studies [1,16] indicate that persons in noisy neighbourhoods have more admissions to mental hospitals, more consultations for emotional disturbances, and a greater incidence of drug treatment for personality disorders. Again, however, it is difficult to dissociate socio-economic factors from health effects, since lower income groups tend to locate in noisier neighbourhoods and they are also the group most susceptible to psychological disturbance.

The degree of annoyance to persons can be gauged from questioning, as in social surveys, or from unsolicited community reaction. It has been well documented that annoyance is much affected by the circumstances and character of the noise.

It is perhaps worthy of note that in the many studies of community response to noise, no special characteristics have been identified among those who complain.[27] The Complainants are but a small proportion of those who would express annoyance if directly questions. The following three

paragraphs describe annoyance effects due to airport noise; expert opinion indicates similar response to traffic noise.

One study investigated[19] the annoyance/complainant relationship and expressed it as follows:

$h = 196 + 2c$, where h = highly annoyed persons per thousand and c = number of complaints per thousand

At 60 dBA noise, individual complaints to operators or public officials become fairly general. This seems to be the highest level a community will tolerate without serious objection[26,35] (and see Appendix 2).

People begin to cite noise as a reason for moving to a different neighbourhood, at levels of 55 dB (Ldn)*. It has been calculated that at this level, 1% of the population might complain and 17% express a high degree of annoyance in social surveys.[7]

Finally, it may be observed that the community reaction to noise is likely to be more marked in rural and suburban areas, and that given levels will be less well tolerated at night or in the evening compared to working hours, and in summer compared to winter.

CONCLUSION

Non-auditory effects of noise on health undoubtedly occur but are difficult to equate with precise levels of sound. It is not yet possible to correlate the physiological effects of noise with susceptibility towards disease. Research in this area should continue with long-term epidemiological studies on human populations being emphasized. Results may be expected to shed some light on noise-tolerant and noise-sensitive personalities.

Psychological effects of noise are definite. Mental disorders may be initiated or aggravated by noise but elucidation of the cause-effect relationship is clouded by a variety of social and environmental factors influencing the human response to noise. The need to preserve an environment in which speech communication can occur without hindrance is essential to man's mental health and development.

Noise-induced sleep disturbance has been well documented. It is known to be desirable for persons to sleep in low noise environments (35-40 dBA) though sleep is possible at levels well above this.

The recommendation based on the current state of knowledge is that Ldn 55 dBA is a desirable level in residential neighbourhoods; it should be sought and planned for whenever possible. Although primarily designed to permit speech communication and minimize annoyance and public complaint, this level is requisite to protect the public health with an adequate margin of safety.**

The noise levels recommended for health reasons would cause no permanent hearing loss over the long term. Note, however, that standards above

---

*Ldn = average sound pressure level (not arithmetic average) over a 24 hour period with an additional 10 dB weighting during the night time (2200-0700 hours).

** U.S. Environmental Protection Agency recommendation (Appendix 3) supported by similar standards set by the International Standards Organization, Ontario Department of Environment and supported by the Environment Council of Alberta report "Noise in the Human Environment", Volume 1.

those recommended, even by 5-10 decibels per 24 hour period, might induce some degree of community annoyance and hearing loss in individuals. This knowledge, combined with allowance for persons whose employment or recreation requires a quiet recovery atmosphere, helps sustain the argument against mitigation of the recommended standard.

One of the less enviable achievements of twentieth century man has been the progressive degradation of the beauty and peacefulness of his environment. Urban traffic has been a significant contributor to this trend, and the noise it generates has been shown to be a source of stress and to have other adverse effects on health. The city is being presented with an opportunity to plan effective solutions to this problem and the key element in any such plan should be adoption and phased implementation of the recommended noise level standards.

Appendices 1, 2, 3; Bibliography

Prepared by:
Edmonton Local Board of Health
1980 05 27

Appendix 1

Table 3

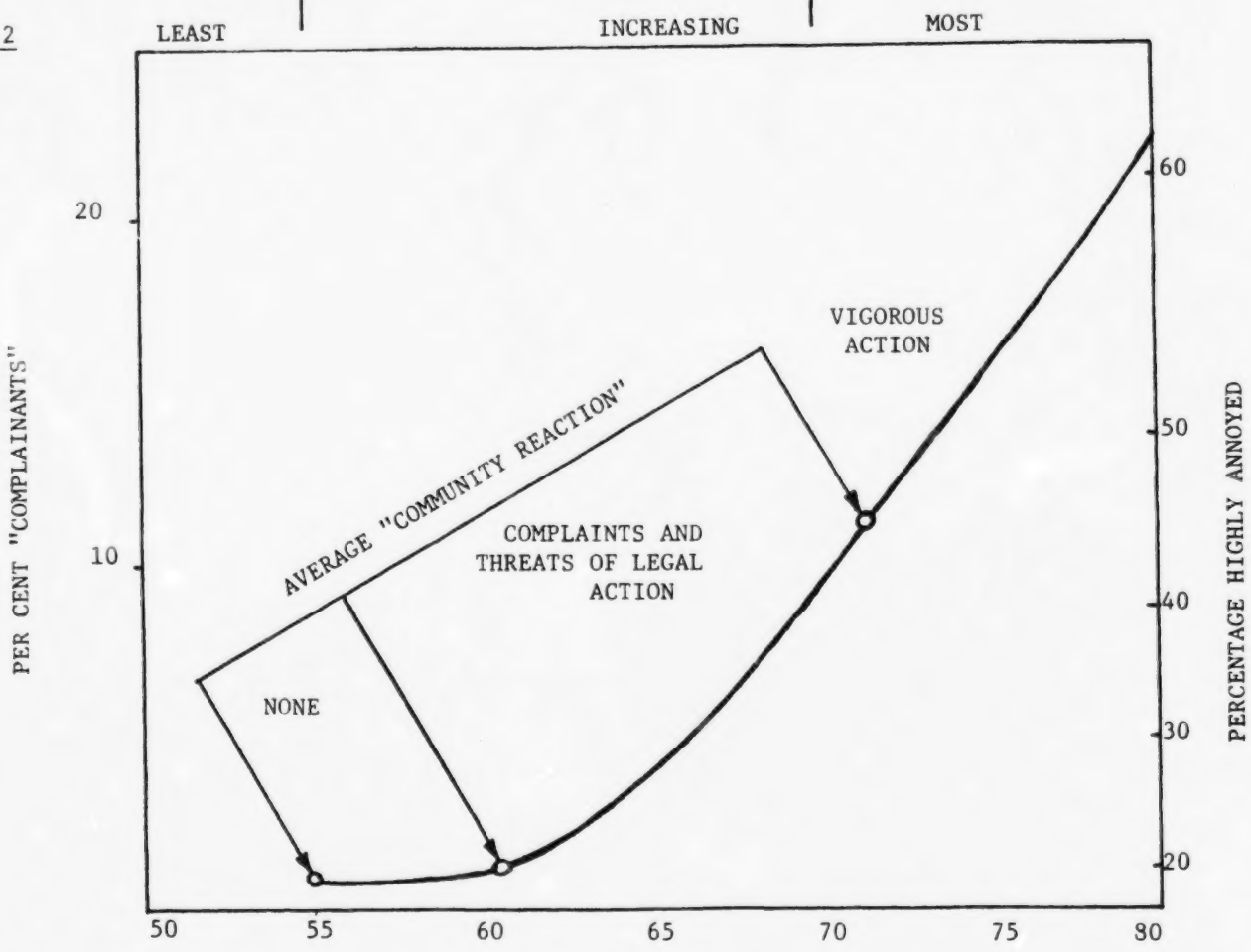
SUMMARY OF HUMAN EFFECTS IN TERMS OF SPEECH COMMUNICATION COMMUNITY REACTION, COMPLAINTS, ANNOYANCE AND ATTITUDE TOWARDS AREA ASSOCIATED WITH AN OUTDOOR DAY/NIGHT SOUND LEVEL OF 55 dB re 20 MICROPASCALS

TYPE OF EFFECT	MAGNITUDE OF EFFECT
Speech - Indoors	100% sentence intelligibility (average) with a 5 dB margin of safety
- Outdoors	100% sentence intelligibility (average) at 0.35 meters
	99% sentence intelligibility (average) at 1.0 meters
	95% sentence intelligibility (average) at 3.5 meters

Source: Information on Levels of Environmental Noise Requisite to Protect the Public Health and Welfare with an Adequate Margin of Safety, Environmental Protection Agency, March 1974, p. 23.

APPENDIX 2

SUMMARY OF ANNOYANCE SURVEY AND COMMUNITY ACTION RESULTS



Source: U.S. Environmental Protection Agency, 1974 "Levels" Report 35

Information of Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety.

Appendix 3

Table 4

YEARLY AVERAGE EQUIVALENT SOUND LEVELS IDENTIFIED AS REQUISITE TO PROTECT THE PUBLIC HEALTH AND WELFARE WITH AN ADEQUATE MARGIN OF SAFETY

	Measure	Indoor			Outdoor		
		Activity Interference	Hearing Loss Consideration	To Protect Against Both Effects	Activity Interference	Hearing Loss Consideration	To Protect Against Both Effects
Residential with Outside Space and Farm Residences	Ldn Leq(24)	45	70	45	55	70	55
Residential with No Outside Space	Ldn	45	70	45			
Commercial	Leq(24)	(a)	70	70(c)	(a)	70	70(c)
Inside Transportation	Leq(24)	(a)	70	(a)			
Industrial	Leq(24) (d)	(a)	70	70(c)	(a)	70	70(c)
Hospitals	Ldn Leq(24)	45	70	45	55	70	55
Educational	Leq(24) Leq(24) (d)	45	70	45	55	70	55
Recreational Areas	Leq(24)	(a)	70	70(c)	(a)	70	70(c)
Farm Land and General Unpopulated Land	Leq(24)				(a)	70	70(c)

Code

a. Since different types of activities appear to be associated with different levels, identification of a miximum level for activity interference may be difficult except in those circumstances where speech communication is a critical activity (See Figure D-2 for noise levels as a function of distance which allows satisfactory communication).
b. Based on lowest level.
c. Based only on hearing loss.
d. An Leq(8) of 75dB may identified in these situations so long as the exposure over the remaining 16 hours per day is low enough to result in a negligible contribution to the 24 hour average, i.e. no greater than an leq of 60 dB.

Note: Explanation of identified level for hearing loss. The exposure period which results in hearing loss at the identfied level is 40 years.

* Reflects energy rather than arithmetic averages.

Source: p. 29, U.S. Environmental Protection Agency, 1974, "Levels" Report.

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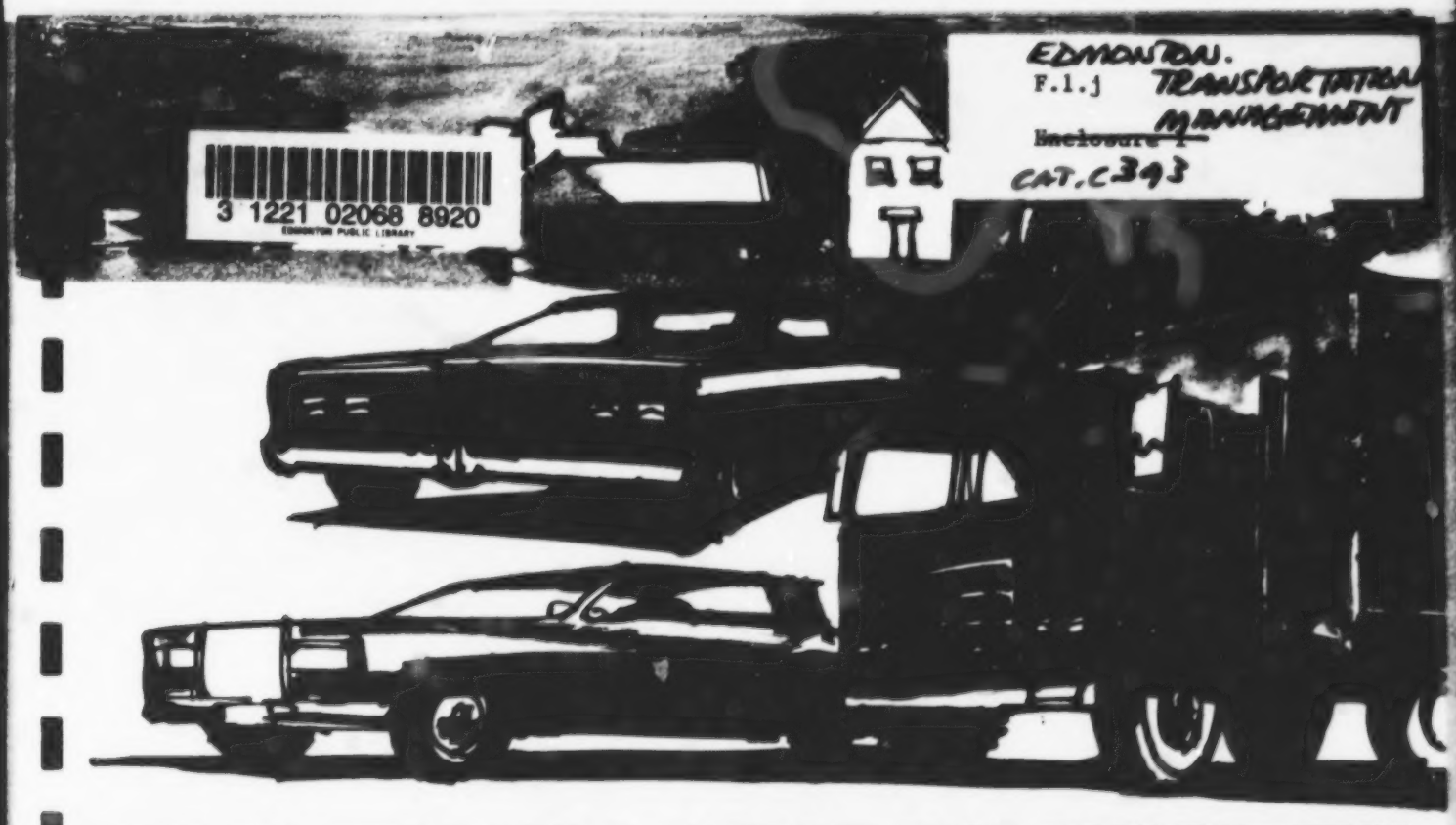
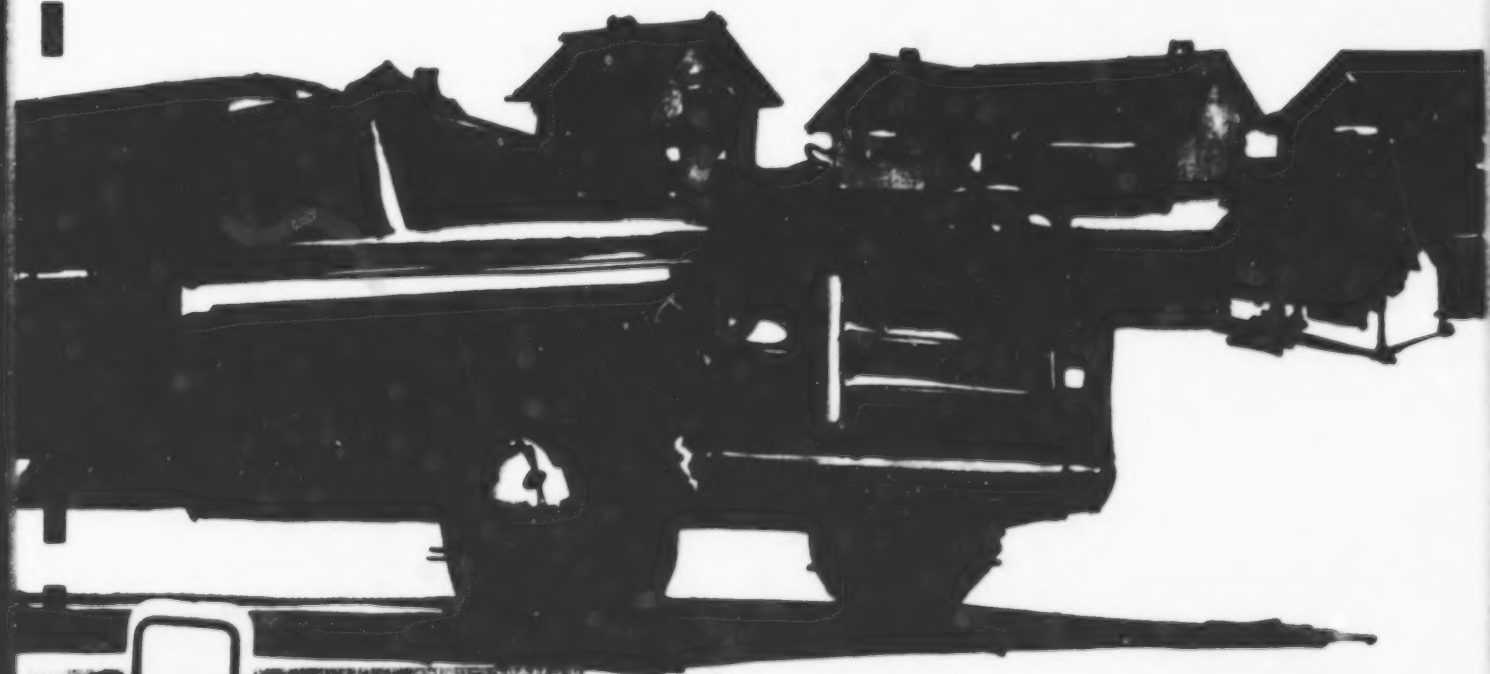


URBAN TRAFFIC NOISE POLICY STUDY

STAGE II — VOLUME I: Summary and Recommendation Report



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URBAN TRAFFIC NOISE POLICY STUDY STAGE II

VOLUME I:

SUMMARY AND RECOMMENDATION REPORT

TSR/30/83

Prepared by:

Transportation Management Department

PREFACE

The Urban Traffic Noise Policy Study (UTNPS) was initiated at the request of City Council at the Aldermanic Seminar on Transportation Issues, held on 1978 07 14. The principle objective of the study was to evaluate and recommend acceptable residential noise level standards and alternative noise control measures in order to achieve the overall goal of reducing the amount of residential land adversely affected by traffic noise in Edmonton.

A two stage approach was taken to achieve this objective. Stage I, of the UTNPS Study, presented to City Council as information on 1980 07 09, reviewed the social-environmental, economic and health related impacts of traffic noise on residential land uses; identified current residential noise standards, policies and guidelines in use throughout North America and Europe; and carried out a preliminary assessment of arterial roadway traffic noise levels within existing areas of the City. UTNPS Stage II, which is summarized within this report, develops, evaluates and selects acceptable residential noise level standards and identifies means to achieve those standards through: i) amendments to government policies and programs; ii) techniques for achieving the noise standards in land use and transportation planning; and iii) municipal noise attenuation and information programs.

The Urban Traffic Noise Policy Study Stage II is documented in three reports: UTNPS Stage II Volume I: Summary and Recommendation Report (TSR/30/83); UTNPS Stage II Volume II: Evaluation and Selection of Residential Noise Level Standards (TSR/31/83); and UTNPS Stage II Volume III: Implementation Strategies (TSR/32/83). The purpose of Volume I, is to provide an historical perspective of the Urban Traffic Noise Policy Study and a summary of the methodological framework, study limitations, findings and recommendations of the Study.

The purpose of Volume II, is to provide more detailed documentation of the criteria used to evaluate alternative noise level standards, and the analysis and evaluation of each criterion, the selection results and associated implementation responsibilities. The purpose of Volume III is to document the various means to achieve those standards through implementation policies, guidelines, programs and responsible parties.

The Urban Traffic Noise Policy Study Stage II commenced on 1982 03 01 under the coordination of the Projects, Policy and Procedures Section of the Transportation Management Department. The review was conducted with the cooperation and input of the Assessment, Bylaw Enforcement, Edmonton Local Board of Health, Engineering, Law, Parks and Recreation, Planning, Police, and Real Estate and Housing Departments. In addition, cooperation and input were received from the Alberta Trucking Association, Alberta Association of Architects, Association of Professional Engineers, Geologists and Geophysicists of Alberta, Urban Development Institute, Housing and Urban Development Association of Canada, City of Calgary Transportation Department, Transport Canada, National Research Council, Canada Mortgage and Housing Corporation, Alberta Transportation, Alberta Municipal Affairs and the Environment Council of Alberta. The project team included J. Meyer, W. Oakes, B. Priebe, D. Langille and G. Latham.

We would like to express our appreciation to all those who assisted us on this study.

R. H. David
General Manager and City Engineer
TRANSPORTATION MANAGEMENT DEPARTMENT

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CHAPTER 1
INTRODUCTION

The purpose of the Urban Traffic Noise Policy Study Stage II: Volume I Summary and Recommendation Report (TSR/30/83) is to provide a summary of the residential noise level standards and alternative noise control strategy findings and recommendations. Chapter 2 outlines an historical review of the study mandate and relevant background events. Chapter 3 presents a summary of the study limitations and assumptions, methodology, and findings including a brief summary of the evaluation undertaken of alternative noise level standards and the review of various implementation strategies. Chapter 4 provides a summary of recommendation statements while Appendix I provides a matrix that presents recommendations, their rationale and further action required. Appendix II presents the responsibilities for implementing the recommendations. Appendix III lists a summary of the effects of noise. Appendix IV outlines procedures for measuring and predicting traffic noise levels. Appendix V outlines interim acoustical barrier design guidelines, while Appendix VI is a glossary of terms found throughout the report. Appendix VII provides a listing of reference documents.

Detailed background documentation is provided in UTNPS Stage II Volume II: Evaluation and Selection of Residential Noise Level Standards (TSR/31/83) and UTNPS Stage II Volume III: Implementation Strategies (TSR/32/83) that are available for review upon request. In addition, three working papers were prepared that provide detailed information on selected topics. They include UTNPS Stage II Working Paper No. 1: Review of Governmental Traffic Noise Legislation and Policies: UTNPS Stage II Working Paper No. 2: Identification of Noise Impacts and Issues; and UTNPS Stage II Working Paper No. 3: Municipal Noise Abatement Bylaw Review.

The recommendations of the Urban Traffic Noise Policy Study were selected to provide acceptable noise level standards and implementation strategies from a health and welfare perspective that were technically, administratively and economically feasible to implement. These are based on the findings from an extensive State-of-the-Art review and an examination of Municipal and Senior Government policy and program areas that have potential to create an acceptable urban sound environment.

CHAPTER 2

BACKGROUND HISTORY OF THE URBAN TRAFFIC NOISE POLICY STUDY

Road traffic noise is recognized world wide as contributing to a general deterioration of the urban environment. As a result of increasing traffic volumes and consequent higher levels of noise, public concern regarding the control and effects of urban traffic noise is rapidly increasing, as evidenced by the numerous concerns recently expressed by both the public and City Council. Some significant advancements have been made in the reduction of traffic noise at its source, namely vehicle noise abatement, however, noise cannot be completely eliminated by this means. In recognition of this fact, it has been found essential that standards, guidelines and procedures be developed to deal with traffic noise in the land use and transportation planning processes. In addition, since Federal and Provincial policies and programs dealing with traffic noise are limited in this area, and the fact that the primary responsibility for integrating traffic noise considerations into the planning process rests with local governments, which have control over actual land development and transportation system improvements, it can be reasonably concluded that the problem must be dealt with at the municipal level. However, cooperation is also required from senior levels of government in order for enabling legislation and related programs to be amended to address and assist with the mitigation of the municipal traffic noise.

The Urban Traffic Noise Policy Study originated at the Aldermanic Seminar on Transportation Issues, held on 1978 07 14, when Council reviewed various roadway noise control policy issues and subsequently directed the Administration to proceed with a comprehensive noise study to address:

i) establishment of Design Noise Levels and preferable method of obtaining acceptable levels,
ii) City of Edmonton's 200 foot setback policy,
iii) problems of enforcement of the existing Noise Bylaw No. 4110,

iv) experimental noise barrier program, identification of priority areas where the Province should be requested to initiate further action.

This policy issue has been included in the Local Policy Plan since 1981. The City of Edmonton's Local Policy Plan 1981-85 identified a need for a policy study to review the traffic noise problem. This policy issue was carried over to the 1982-1986 Local Policy Plan which identified traffic noise attenuation as a policy issue that should be dealt with by examining traffic noise levels throughout the City and subsequently recommending the use of appropriate control measures. The directive given in this Local Policy Plan stated:

> "That City Council adopt appropriate comprenhensive noise control policies based on recommendations currently being prepared."

Following the Aldermanic Seminar, the Administration initiated a two stage approach to study the urban traffic noise problem. Stage I was to assess the extent of the traffic noise problem in Edmonton, with Stage II to provide policies, standards and implementation strategies to mitigate the identified traffic noise problem. Stage I of the Urban Traffic Noise Policy Study was undertaken by the consulting firm of Marshall, Macklin and Monaghan Limited.* This stage of the study, completed 1980 06 02, reviewed the social-environmental, economic and health related impacts of traffic noise on residential land uses; identified current residential noise standards, policies and guidelines in use throughout North America and Europe; and, carried out a preliminary assessment of arterial roadway traffic noise levels within existing residential areas in the City.

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* City of Edmonton, Transportation Management Department, "Urban Traffic Noise Policy Study Stage I: A Perspective", 1980.

The preliminary assessment of noise in existing residential areas identified that in 1980, approximately 130,000 persons or 23 percent of the City of Edmonton population, resided adjacent to arterial roads. Of these, approximately 18,500 persons were exposed to outdoor noise levels less than or equal to 55 dBA Ldn, and approximately 16,500 persons were exposed to outdoor levels ranging between 55 and 60 dBA Ldn. The remaining 95,000 persons were exposed to outdoor levels ranging from 60 to 75 dBA Ldn. A review of international noise level standards indicated that the predominant objective noise level ranged between 55 to 65 dBA Leq with most jurisdictions identifying levels in excess of 70 dBA Leq to be unacceptable. From the study results, it was concluded that to varying degrees, many residents residing adjacent to arterial roads in Edmonton are subject to socio-environmental, economic and health related traffic noise impacts and that an additional Stage II study be undertaken to establish a comprehensive traffic noise policy for the City of Edmonton in order to mitigate these impacts of traffic noise.

This report was submitted to City Council on 1980 07 08, and was received as information. Subsequently, City Council directed the Administration to proceed with Stage II of the Urban Traffic Noise Policy Study for the purpose of:

- developing, evaluating and selecting acceptable residential noise level standards; and
- identifying means to achieve those standards through implementation policies, guidelines and programs.

An additional directive was given by Council on 1981 07 07:

- to investigate the feasibility of reducing the existing permitted decibel levels for vehicles, under the City Noise Bylaw.

In order to carry out these directives, the Transportation Management Department (formerly the Transportation Systems Design Department), prepared a Terms of Reference for Stage II of the Urban Traffic Noise Policy Study which set out the study objectives, limitations and assumptions, study activities, work program, study members and responsibilities and study costs, which was received as information by City Council on 1982 08 13. The primary study activities included: the evaluation and selection of a residential noise level standard; a review of the Municipal Noise Abatement Bylaw; and a review of various administrative and physical noise mechanisms and programs to minimize the occurance of new noise problems and to help mitigate existing noise problems.

The primary responsibilities for developing the Urban Traffic Noise Policy remained with the Projects, Policy and Procedures Section (formerly the Projects and Planning Services Section), Transportation Management Department. However, various Civic Departments and outside agencies participated in the study as noted in the preface of this report. A summary of responsibilities is provided in the matrix illustrated in Figure 2.1. The major responsibility of the other Departments and agencies was to assist the Study Team in the preparation, review and evaluation of an Urban Traffic Noise Policy by providing:

i) technical advice and information as required;

ii) clarification of existing or emerging policies;

iii) communication and coordination with respective Branches or Sections in each relevant department or agency;

iv) identification of priority areas or areas of concern that the study should address to meet the needs and expectations of the parties involved; and

v) an identification and facilitation of policies and programs to assist in implementing the study recommendations.

RESPONSIBILITY MATRIX

STUDY ACTIVITY	T.M.D.			ENGINEERING		PLANNING		BYLAW	POLICE	HEALTH	LAW	PARKS & REC	RE & H	PUBLIC & OUTSIDE AGENCIES
	P&PS	FP	SP	OPER	MAT'L TEST	LAND USE	GMP							
1 TERMS OF REFERENCE	■	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
2. REVIEW EXISTING GOVERNMENT /MUNICIPAL NOISE LEGISLATION	■													
3 IDENTIFICATION OF NOISE IMPACTS AND ISSUES	■									●				●
4 REVIEW OF EXISTING MUNICIPAL NOISE ABATEMENT BYLAW	■	▲	▲	▲	▲	▲	▲	●	●	▲	●	▲	▲	▲
5 ANALYSIS OF EXCESSIVE TRAFFIC NOISE LOCATIONS	■	▲	●	▲	●	▲	▲	▲	▲	▲	▲	▲	▲	▲
6 EVALUATION AND SELECTION OF NOISE LEVEL STANDARDS	■	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
7 PUBLIC INFORMATION EXCHANGE	■													●
8 PREPARE IMPLEMENTATION STRATEGIES	■			●	●	●	●			●		●	●	
9 PREPARE DRAFT REPORT	■	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
10 PREPARE FINAL REPORT	■	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
11 G.M.P. & LAND USE BYLAW AMENDMENTS AND PUBLIC HEARINGS	■					■	■							

■ MAJOR RESPONSIBILITY (Initiate and Complete Activity)
● SECONDARY RESPONSIBILITY (Provide Information for a Component of Study)
▲ MINOR RESPONSIBILITY (Review and Comment)

FIGURE 2.1 RESPONSIBILITY MATRIX

Representatives from participating Departments and outside agencies were contacted directly by the Transportation Management Department as required.

The public was afforded the opportunity to provide input into the study in conjunction with Functional Roadway Plan meetings, when traffic noise was perceived as an issue, in order to educate the public with general principles of traffic noise propagation and to familiarize citizens with the study objectives and activities. A display as well as handout information was prepared for these meetings. Interested citizens were also given the opportunity to review the draft study reports upon request. Furthermore, public interests were incorporated in the evaluation of alternative noise level standards by selecting standards from a health, welfare and economic perspective.

The UTNPS Stage II study is documented in three separate volumes. Volume I entitled, UTNPS Stage II Volume I: Summary and Recommendations (TSR/30/83), presents an overview of the Study's findings and recommendations for Council's consideration, that was derived from the detailed study findings documented in Volumes II and III.

Volume II, entitled, UTNPS Stage II Volume II: Evaluation and Selection of a Residential Noise Level Standard (TSR/31/83), contains an analysis of alternative residential noise level standards based upon evaluation criteria including: a noise policy state-of-the-art review; an analysis of health and welfare effects; an analysis of economic reasonableness; and an analysis of administrative acceptability. From this evaluation, acceptable residential noise level standards were determined. Also implementation responsibilities for the City, the developer and the resident were outlined in order to facilitate the implementation of the noise level standards.

Volume III, entitled, UTNPS Stage II Volume III: Implementation Strategies (TSR/32/83), examines a series of implementation strategies for the noise standards related to: i) amendments to senior government and municipal policy; ii) appropriate physical noise attenuation techniques for land use and transportation planning; iii) municipal noise abatement and information programs; iv) other abatement measures for application by the Municipality.

The methodology and findings of the UTNPS Stage II Study are summarized in the following Chapter.

CHAPTER 3
SUMMARY OF STUDY LIMITATIONS, METHODOLOGY AND FINDINGS

3.1 INTRODUCTION

This chapter provides a summary of the methodological framework used to select acceptable residential noise level standards and to review implementation strategies and associated responsibilities that would integrate the consideration of traffic noise into the overall comprehensive planning process. In addition an explanation of the study limitations is presented. The background documentation, from which this information was derived, is contained in UTNPS Stage II Volume II: Evaluation and Selection of Residential Noise Level Standards (TSR/31/83) and UTNPS Stage II Volume III: Implementation Strategies (TSR/32/83).

3.2 STUDY LIMITATIONS

A number of study limitations were recognized due to physical, technical and economic constraints involved in mitigating all residential noise problems throughout the City. These were based on practical experiences in Edmonton and other North American municipalities. These study limitations were incorporated into and influenced the methodological approach to the Urban Traffic Noise Policy Study and the subsequent findings. The study limitations are as follows:

i) Many sources of noise contribute to the overall urban noise problem including train, aircraft, commercial and industrial activities, machinery around the home, animal and human sources. The aim of this study, however, is to focus on vehicular 'traffic' noise sources including trucks and automobiles that utilize the City roadway network adjacent to residential areas.

ii) A discretionary range for a noise level standard was considered necessary as a single rigid noise level standard imposed on new residential development, such as new subdivisions, may be found impractical and unattainable in existing developed situations, such as where infill housing is proposed. Existing situations are sometimes constrained by the nature of existing land uses and lack of space for applying low cost attenuation techniques.

iii) It was recognized that the outdoor amenity area is an integral living space component of residential property under three storeys. Consequently, noise level standards are based upon the exterior sound level that would occur within this area. Specifically this area is defined as the outdoor living area immediately adjacent to the housing unit, provided and designed for active or passive recreation and enjoyment of the occupants of a residential development, which may be for private or communal use and owned individually or in common. The rationale for this limitation is based on the fact that when the outdoor noise level for buildings less than three storeys is acceptable, then an acceptable indoor noise level could normally be met by the building construction complying with the Alberta Building Code. In other words, if the outdoor noise level is within 60-65 dBA Leq, the building face will reduce interior noise levels by 15-20 dBA and thereby result in an acceptable interior sound environment of 40-45 dBA Leq. For residential buildings of three storeys or more, the noise level will be measured at the facade of the dwelling units, as noise measurements in the outdoor amenity area are not indicative of actual noise levels for medium to high rise buildings because of greater building mass and height.

iv) This study recommends a noise level standard that a majority of the population may consider reasonable, recognizing the fact that there are individual variations in noise tolerance from person to person.

v) In the case of single family homes fronting-on an arterial roadway and multi-storey buildings where 81% of the residents exposed to excessive traffic noise along arterial roadways, it is not feasible to mitigate excessive traffic noise using conventional attenuation devices. In these situations an acoustical barrier is impractical because of the lack of space, elimination of access to the buildings, barrier height limitations, and aesthetic consequences. Recognizing this limitation, it is the intent of the study to recommend measures that would prevent these types of noise problems from occuring in the future.

3.3 METHODOLOGY

The existing interim noise level standard adopted by City Council was based on a review of noise policies adopted elsewhere in North America and applies solely to new residential development adjacent to designated truck routes. It does not apply to new residential development adjacent to arterials not designated as truck routes or within existing residential areas whether or not the development is adjacent to a truck route.

The primary objective of Stage II of the UTNPS Study is to determine noise level standards that are based on a review of health and welfare criteria, as well as experience elsewhere, that would be technically, economically and administratively feasible to implement on a city-wide basis.

In addition, the study examines alternative implementation strategies to:

- prevent new traffic noise problems from occuring adjacent to noise sensitive land uses by ensuring measures are included in both residential development and functional roadway projects; and
- to reduce existing residential noise problems by encouraging noise insensitive redevelopment or by applying physical noise abatement measures.

These objectives were accomplished using two methodological frameworks: one for selecting acceptable residential noise level standards; and the other for determining appropriate implementation strategies. A summary of these frameworks is as follows:

3.3.1 Evaluation and Selection of Acceptable Residential Noise Level Standards

The evaluation and selection of acceptable residential noise level standards was based on a review of existing Canadian and U.S. Noise policies and standards and through an analysis of the effects of various noise levels on selected health, welfare, economic and administrative criteria relevant to the Edmonton situation. This evaluation, which is presented in detail in the Urban Traffic Noise Policy Study Stage II Volume II: Evaluation and Selection of a Residential Noise Level Standard (TSR/31/83), included an extensive literature review, an analysis of economic data and noise level data collected in the field, a review of existing federal, provincial and municipal policies and procedures and an examination of documentation provided by the City of Edmonton Health and Assessment Departments. With the application of this information as a basis, a noise level standard was selected that would protect the public health and welfare aspects of the urban environment. A feasibility

analysis of this standard was conducted including technological, economic, legal and administrative factors. It was the application of these constraints that differentiated between desirable noise levels and achievable noise standards.

Specifically, acceptable residential noise level standards were evaluated and selected according to the following criteria, which were felt to represent the most critical and quantifiable effects of setting a residential noise level standard on the Public, the City and the Developer:

i) State-of-the-Art Review:

The standard should be comparable to current effective and efficient noise level standards approved by other Canadian and U.S. Senior and Local Governments.

ii) Health Effects:

The noise level standard should not have potential to induce hearing loss in individuals.

iii) Welfare Effects:

The noise level standard should not create excessive public concerns, dissatisfaction or complaints caused from speech interference, sleep interference and general annoyance.

iv) Economic Reasonableness:

The noise level standard should not cause an unreasonable economic burden to implement on behalf of either the City, Developer or affected Resident.

v) Administratively Acceptable:

The noise level standard selected should be administratively feasible.

3.3.2 Implementation Strategies

The review of alternative implementation strategies was divided into three components: i) policy amendments and formulation; ii) techniques for achieving the noise standards in land use and transportation planning and; iii) municipal noise attenuation and information programs.

i) Policy Amendments and Formulation

The selection of appropriate implementation strategies was determined by first examining noise policy areas that were consistent with the existing federal, provincial and municipal government responsibilities, legislation and administrative mechanisms, for the purpose of encouraging, improving or regulating noise legislation in order to reduce the impacts of traffic noise on residential areas. In addition, an attempt was made to integrate the recommended noise level standard and associated policies into the overall comprehensive planning and interagency/intergovernmental coordination process. The purpose of considering noise in the land use planning process is not to prevent development but rather to encourage development that is compatible with various noise levels. The objective is to guide noise sensitive land uses away from the noise and encourage non-sensitive land uses where there is noise. Where this is not possible, measures should be included in development projects to reduce the effects of the noise.

The required amendments to existing policy were determined through written and oral correspondence with the affected government agencies and a thorough examination of the noise control potential of existing legislation of both senior and municipal levels of government. The administrative mechanisms that were considered included:

Senior Government Legislation:

- Vehicle noise emission regulations;
- Tire standards and pavement design standards;
- Building code regulations;
- Health regulations;
- Planning Act regulations;
- Provincial cost sharing of noise attenuation expenses; and
- Funding assistance for Retrofit Program through existing Federal home improvement programs.

Municipal Government Legislation:

- General Municipal Plan;
- Land Use Bylaw;
- Terms of References for Area Redevelopment Plans, Area Structure Plans and Neighbourhood Structure Plans;
- Traffic Management;
- Municipal Noise Abatement Bylaw; and
- Property Tax Assessment.

ii) Techniques for Achieving the Noise Standards in Land Use and Transportation Planning

The second component of the implementation strategy was to examine alternative physical noise control techniques that are available to architects, planners, developers and roadway engineers to achieve

acceptable noise levels in newly developing areas, locations undergoing residential redevelopment and where roadway construction or improvements are proposed. This information was gathered from an extensive literature search as well as from municipal procedures and practices that have evolved on a guidelines basis over the past four years, particularly with acoustical barriers.

The following physical attenuation techniques were considered:

- Spatial Separation;
- Land Use Barriers;
- Acoustical Barriers;
- Architectural Design; and
- Acoustical Construction Techniques.

These physical techniques vary in terms of noise reduction characteristics, costs, marketability, and applicability to specific locations and conditions. In addition, the effectiveness of any given technique is a function of the specific noise situation and the way the technique is applied. The purpose of this Section was to determine the most effective alternatives which could be considered in the land use, architectural, engineering and transportation planning processes and to provide guidelines in their use. The most effective approach will be a combination of techniques with the decision regarding the most appropriate mechanism being made by the proponents of residential development projects. The primary stipulation in using these techniques is to ensure that the recommended noise standard is met and that the proposed residential land use complies with applicable development regulations specified in the Land Use Bylaw.

iii) Municipal Noise Attenuation and Information Programs

The third and final component of the implementation strategy was to investigate alternative noise abatement program areas that the municipality could implement to reduce excessive traffic noise impacts on existing residential areas. These residential areas include those that are not being considered for noise attenuation facilities as part of a proposed roadway improvement or area or neighbourhood structure plan and are not proposed for land use redistricting in conjunction with an area redevelopment plan or a redevelopment proposal. Two program areas were examined:

- A Barrier Priorization Program and;
- A Citizen Information Program.

The Barrier Priorization Program entailed the priorization of sites adjacent to arterial roadways to determine the most critical residential areas requiring the installation of noise barriers. Candidate sites were 'short listed' based upon site criteria including: lot orientation; local site conditions; the proximity of an arterial roadway; actual noise levels; and the absence of any existing noise attenuation facilities or future plans for constructing facilities. This information was gathered from site surveys, aerial photographs and noise monitoring surveys. The candidate sites were ranked based upon a benefit/cost index with a fixed unit cost for barrier construction being assumed. For this process, the numerical relationship of the index number increased directly with the existing levels of traffic noise and the number of residences to be protected. Those locations that were ranked high by the benefit/cost index with noise levels of 70 dBA Leq (24) or greater were considered cost effective sites for the construction of a barrier.

A Citizen Information Program was examined with the purpose of informing the public of the general principles of traffic noise propagation and to give advice regarding cost effective noise attenuation measures that may be voluntarily implemented to reduce the impact of traffic noise upon the indoor sound environment. Federal grant funding aid to undertake the necessary acoustical renovations is also explored. Another important purpose of this program was to inform residents of existing municipal noise policies and the responsibilities of the City, the Developer and the Resident in terms of attenuating existing residential noise problems. This program will be particularly useful for those property owners with moderate noise levels (65-70 dBA Leq), that do not warrent the installation of noise barriers or purchase of property, yet are willing to reduce their noise problem at their own expense.

3.4 FINDINGS

The findings of the Urban Traffic Noise Policy Study Stage II indicated the need for revised residential noise level standards and for the development of attendant implementation strategies. These results along with a formalization of noise attenuation implementation responsibilities of the City, the Developer and the Resident and other affected agencies are summarized in this section. (For a more detailed review of the findings, refer to Appendix I of this report and UTNPS Stage II Volume II: Evaluation and Selection of a Residential Noise Level Standard (TSR/31/83) and UTNPS Stage II Volume III: Implementation Strategies (TSR/32/83).

The recommendations were developed by members of the Transportation Management Department Study team based on the evaluation of the findings. Draft recommendations were reviewed by all study participants, with emphasis on the policy areas where their responsibility for implementation has been indicated. The concerns and comments of the

study members were evaluated and for the most part incorporated into the finalization of the study recommendations.

3.4.1 Evaluation and Selection of Acceptable Residential Noise Level Standards

An analysis was undertaken of alternative noise level standards using a number of evaluation criteria to select the most appropriate standards. Criteria included a State-of-the-Art review of current noise standards approved by various Canadian and U.S. Federal, Provincial, State and Municipal Governments as well as a review of the health, welfare, economic and administrative impacts of selecting various standards. A summary is presented below.

3.4.1.1 State-of-the-Art Review

The State-of-the-Art Review examined traffic noise control legislation and policies that have been adopted in North America for the purpose of assisting in the selection and recommendation of an acceptable residential noise level standard for Edmonton. The major task of this exercise was to document existing government noise policies, taking into account the existing standards, policy rationale, implementation strategies and the effectiveness of the examined policies.

The study findings indicated that noise standards based solely upon health and welfare criteria were very stringent with acceptable noise levels in the range of 55 to 60 dBA Leq. Such standards have proven extremely difficult to enforce and have been applied only in new residential situations where a wide variety of noise abatement options may be applied. Noise standards based upon economic, administrative and technical criteria allowed more flexibility and generally, were in the range of 60 to 65 dBA Leq. Standards in this range were widely

adopted and perceived as more realistic in terms of implementation and at the same time provided acoustical protection for the majority of the urban population. In addition, noise levels set within this range can provide for acceptable indoor noise levels (45 dBA) if a dwelling unit is constructed in accordance with the requirements of the Alberta Building Code.

A noise standard range of 60 to 65 dBA Leq provides the flexibility required to address any technical and economic constraints and additionally, take into account health and welfare concerns. (A comprehensive review of traffic noise legislation and policies in North America is documented in the Urban Traffic Noise Policy Study Stage II Volume II: Evaluation and Selection of a Residential Noise Level Standard (TSR/31/83) and in the Review of Governmental Traffic Noise Legislation and Policies, Working Paper #1.)

3.4.1.2 Health Effects

In light of health concerns, it was determined that noise level standards should not exceed 70 dBA Leq in order to prevent the occurance of hearing loss due to noise. This level represents the maximum allowable noise environment for existing residential areas, as it is the threshold point whereby hearing impairment may begin to occur. In addition, the psychological effects of noise, such as stress, although difficult to measure, will begin to intensify as the level of annoyance increases and loss of sleep becomes more frequent. These findings were substantiated by the Local Board of Health through an extensive literature search as well as consultation with three medical experts in audiology. (Refer to: Health Effects of Traffic Noise: An Addendum Report, (1982) and in UTNPS Stage II Volume II: Evaluation and Selection of Residential Noise Level Standards (TSR/31/83).)

3.4.1.3 Welfare Effects

Three welfare indicators were also examined to determine the selection of an acceptable noise level standard including interference with speech; interference with sleep; and the degree of annoyance from noise. Individually, these three indicators have been used by U.S. Government agencies as the sole basis for the selection of residential noise level standards.

Speech interference from noise begins to occur at a noise level of approximately 60 to 65 dBA Leq. Above this range, normal conversation becomes more difficult and speakers are required to move closer, raise their voices or cease conversation. This results in increased annoyance and complaints that would contribute to the degradation of the overall neighbourhood environment.

The threshold at which noise begins to interfere with sleep varies with each individual. In general, however, it appears that outdoor noise levels begin to interfere with sleep above 65 dBA Leq. Below this level, sleep interference will not occur, except with a minority of individuals who are more sensitive to noise and consequently easily disturbed from sleep.

Similarly, annoyance effects from noise become significant when noise levels reach above 65 dBA Leq. Even at this noise level, approximately 85% of the public are not highly annoyed, however, noise is likely to be considered an adverse aspect of the neighbourhood environment. Above 65 dBA Leq, community reaction becomes significant to severe and noise becomes one of the important adverse aspects of the community. (A more detailed analysis of these effects is provided in the Identification of Noise Impacts and Issues, Working Paper #2 and in the Urban Traffic Noise Policy Study Stage II Volume II: Evaluation and Selection of a Residential Noise Level Standard, (TSR/31/83).)

3.4.1.4 Economic Reasonableness

The examination of noise policies in use elsewhere in North America as well as the evaluation of health and welfare effects of noise provided a basis supportive of a 60 dBA Leq ,noise standard with an acceptable range of up to 65 dBA Leq for application to new residential development situations. The 5 dBA range allows for the flexibility that is required to address possible technical and economic constraints while maintaining marginal protection for the public from excessive exposure to traffic noise.

A further evaluation was conducted to examine the economic feasibility of implementing this standard within the Edmonton context. The economic effects of the noise standard were determined by examining the responsibilities and consequent attenuation costs required for implementation of the standard by the: i) Municipality; ii) Residents; and iii) Development Industry.

i) Municipal Costs

The costs to the City with respect to the implementation of the noise standard can be divided into two areas: ensuring the attenuation of traffic noise in new residential development situations; and the selective abatement of excessive noise level locations in existing residential development situations as identified in Functional Roadway Planning Studies and the proposed Barrier Priorization Program. These responsibilities of the municipality are specifically stated in Chapter 4, Recommendations Section, Pgs. 43, 44, 49-55.

For new residential development situations, the costs to the City are primarily the salaries of staff responsible for activities undertaken within the development review process. These staff salary costs are difficult to isolate, as the time required varies from situation to situation. The cost of including a traffic noise component within the review process would be minimal. On average it takes less than an hour to review applications to ensure conformity to standards. The average number of new residential development applications per annum is 3165 (1982) of which a limited number are for sites adjacent to arterial roadways.

For existing residential locations adjacent to arterial roadways, the City is committed to providing noise attenuation in conjunction with roadway upgrading projects, where feasible, as recommended in Functional Roadway Planning Studies. These costs incurred in providing noise attenuation facilities vary from situation to situation depending upon: site specific factors, the type of material selected for the attenuation barrier, the noise level reduction required, or in some extreme cases, the need to purchase the noise impacted properties.

However, major capital expenditures are usually associated with noise attenuation. For example, $2,200,000 was allocated for noise attenuation facilities in the Whitemud Functional Planning Study and estimates for the Northeast Corridor Functional Planning Study indicate that $795,000 is required to provide adequate noise attenuation. There are currently four completed Functional Roadway Planning Studies since 1980 that recommend the provision of noise attenuation, of which all are eligible to receive 2/3 cost shared financial

assistance from the Province under the Urban Transportation Assistance Program. In total since 1980, $6,595,000 worth of required noise attenuation facilities have been identified through Functional Roadway Plans.

Although it is more cost efficient to provide noise attenuation concurrently with roadway improvements, it was found necessary to review the noise conditions along arterial roadways not committed to Functional Roadway Studies. This requirement has formed the basis of the proposed Barrier Priorization Program (p. 53). A recent review (1982) of noise levels along the arterial roadway network, however, indicated that at this time no new candidate sites for noise attenuation facilities are required, other than those already addressed in Functional Roadway Plans or Area Structure Plans. Therefore, there is no immediate requirement for noise attenuation capital expenditures, other than funds allocated in the Functional Roadway Plans.

Future expenditures on noise attenuation are dependant upon land use changes, the alteration of truck routes and potential increases in traffic flows along arterial roadways. Traffic noise levels along arterial roadways will be monitored on an annual basis to identify any new noise problem locations. Sites that warrant attenuation, that are technically and economically feasible to abate, will receive consideration through the proposed Noise Barrier Priorization Program or will be addressed in a future Functional Roadway Planning Study. These sites will then be included within the Engineering Department's 5 and 10 Year Transit and Roadway Improvement Program for implementation. More detailed information on Municipal attenuation responsibilities is included in UTNPS Stage II Volume III: Implementation Strategies (TSR/32/83).

ii) Resident Costs

Currently, the residents of Edmonton indirectly share the responsibility for the costs incurred with municipal funded noise barriers through taxation. Municipal funded barriers are either provided under Functional Roadway Plans or will be included within the proposed Barrier Priorization Program. These costs are minimal however, as they are shared by all City residents through general property taxes.

Direct attenuation costs to residents may occur for situations where the City does not identify a noise problem, or where property owners may be very sensitive to noise and wish to achieve noise levels below the standards. For these situations a resident may voluntarily choose to retrofit their dwelling units in order to reduce interior noise levels to an acceptable level of 45 dBA. These costs could range from $500.00 for the acoustical treatment of windows to as high as $5000.00 for sealed residential units with central air conditioning. These expenditures could be reduced however, if financial assistance was available from the Canada Mortgage and Housing Corporation under an existing home improvement grant program. The attenuation responsibility of residents is specifically stated in Chapter 4, Recommendation Section, p. 44. A more detailed examination of acoustical home improvement costs is provided in UTNPS Stage II Volume III: Implementation Strategies (TSR/32/83).

iii) Development Industry Costs

The Development Industry has been made responsible for ensuring that new residential development adjacent to truck routes, include attenuation measures to reduce the effects of noise to the existing noise level standard of

60 dBA Ldn. It is proposed that the Development Industry will be responsible to develop plans adjacent to arterial roadways which include noise insensitive land uses or be prepared to pay the full costs of developing residential land in accordance with the 60 dBA Leq standard. The onus will be on the developer to make this decision and to assume the cost implications if noise attenuation is required, as it is the development which directly benefits from the mitigative measures. The attenuation responsibilites of the Development Industry are specifically stated in Chapter 4, Recommendation Section, p. 43, 44.

The cost implications on the Development Industry to comply with the above attenuation responsibility are difficult to speculate on as they depend upon specific site conditions, the required noise level abatement and the attenuation technique selected. These technical factors effecting the cost of the alternative attenuation measures are outlined in UTNPS Stage II Volume II: Evaluation and Selection of a Residential Noise Level Standard (TSR/31/83).

It is known, however, that noise attenuation costs can be reduced if noise abatement is considered and incorporated early in the planning process. At this time the most cost effective techniques, as determined by the developer, are at their disposal. These techniques include spatial separation, land use barriers, acoustical barriers, architectural design and acoustical construction materials. If land use planning measures are selected (spatial separation or land use barriers), they would eliminate the need for a barrier structure and land for the sole purpose of attenuating traffic noise, as noise attenuation is "built in" to the residential projects. This allows for more developable land and

removes the costs associated with long term maintenance of attenuation facilities. Furthermore, the attenuation costs could be offset through increased marketability of the residential dwelling units from reducing on site traffic noise levels.

3.4.1.5 Administrative Acceptability

As in the economic reasonableness analysis, the evaluation of administrative acceptability was limited to a 60 dBA Leq noise standard. This standard was determined to be acceptable from an examination of noise policies in use elsewhere in North America as well as the evaluation of health and welfare effects of noise. The evaluation of administrative acceptability determined that currently senior government legislation enables the City to adopt a residential noise level standard of its choice. There is not any existing Federal or Provincial legislation regarding residential noise level standards that could be adopted by municipalities at this time. However, it is necessary to amend the Planning Act to enable a municipality to implement a residential noise level standard in the planning process. In fact, the provision of noise attenuation cannot be imposed at the subdivision and redistricting stages of development until the enabling legislation is amended.

The interim noise level standard of 60 dBA Ldn has been effective in controlling noise problems in new residential areas, however, it is not flexible to be used for redevelopment situations that may require less stringent standards because of constraints imposed by the nature of existing land uses and lack of space for applying low cost attenuation techniques. Therefore, it is necessary to allow a range up to 65 dBA Leq that would require the implementation of economically and technically practicable noise attenuation measures for these situations.

In addition, the existing noise descriptor (Ldn) was found to be an inferior descriptor for describing community noise because it: i) increases the time and cost of acoustic measurements; ii) increases the number of calculations; iii) is dependent upon source information over a 24-hour period; and, iv) requires assumptions that introduce errors in the design of noise abatement measures by the arbitrary nature of the 10 dBA nighttime penalty it uses. In comparison the noise descriptor (Leq) is best suited for the City's needs as it: i) correlates with perceived annoyance; ii) does so over a wide range of source conditions; iii) can be used for more than one type of source which allows the overall noise climate to be described; iv) is based on accurate and reasonably inexpensive measurement; and v) is recognized world-wide. (A detailed comparison of the two noise descriptors is outlined in UTNPS Stage II Volume II, Evaluation and Selection of a Residential Noise Level Standard, (TSR/31/83).)

3.4.1.6 Conclusion of the Noise Level Standard Evaluation

In conclusion, the results of this study provide evidence that a residential noise level standard of 60 dBA Leq(24) with a discretionary range up to 65 dBA Leq(24) provides an acceptable sound environment and is the most technically, administratively and economically feasible standard to implement. The lower end of the standard, 60 dBA Leq(24), represents an acceptable noise level with respect to health and welfare concerns. The upper end of the standard, 65 dBA Leq(24), recognizes the technical and economic constraints associated with the application of the standard in existing residential areas. (Appendix IV outlines the data requirements and procedures to be used for the measurement and calculation of traffic noise levels.)

It is important to note, that this recommended noise standard does not guarantee the elimination of all annoyance or disturbance from traffic noise, even in those situations when the standard is met.

3.4.2 Review of Implementation Strategies

Upon selection of an acceptable noise level standard, it was imperative to review possible implementation strategies that may be used to ensure the consideration of the residential noise level standards in the planning process and to generally reduce the amount of land adversely affected by traffic noise. This task resulted in the formation of a multi-facet implementation strategy, as solutions to noise problems are variable depending upon specific noise sources, levels of noise, site conditions, existing legislation and noise control mechanisms.

The evaluation of the noise control mechanisms was divided into three groups: administrative mechanisms; physical noise attenuation techniques and; municipal noise abatement and information programs.

3.4.2.1 Administrative Mechanisms

The examination of possible administation mechanisms, identified a number of policy and program areas within senior levels of government that were deficient in addressing traffic noise concerns, however, with appropriate amendments they offered potential solutions to municipal traffic noise problems.

The following policy and program areas were identified under the jurisdiction of the Federal Government:

- more stringent vehicle noise emission regulations for new vehicles are required.

- research to further reduce engine and tire/pavement noise, as the expertise for this research is available within Transport Canada.

- the restricted use of pocket-type retread tires.

- a 'buy-quiet' policy to give preference to the purchase of quieter vehicles by Federal Departments, in order to reduce the noise impacts of federal owned vehicles.

- amendments to the National Building Code Regulations to address the provision of acceptable interior noise levels in order to regulate the use of acoustically treated building materials and designs for residential dwelling units, in order to meet an acceptable interior noise level.

- amendments to existing CMHC home improvement grant funding programs including RRAP, CHRP, CHIP or another appropriate government grant program to include funding for undertaking acoustical modifications to residential dwelling units in order to achieve acceptable interior noise levels.

The following policy areas were identified under the jurisdiction of the Provincial Government:

- consistent provincial-wide vehicle noise regulations in order to eliminate the problem with variable municipal noise regulations that is encountered by the trucking industry when moving goods from city to city.

- regulation of proper vehicle maintenance by regular vehicle testing to ensure proper vehicle noise emission levels are maintained by vehicle owners.

- a 'buy-quiet' policy to given preference to the purchase of quieter vehicles by Provincial Departments in order to reduce the noise impacts of provincial owned vehicles.

- an agency, identified as a Quiet Communities Directorate, be established within the Provincial Government to provide leadership in achieving a quiet environment in Alberta, as recommended by the Environment Council of Alberta from their public hearings on noise in Alberta.

- amendments to the Alberta Building Code to address the provision of acceptable interior noise levels and to regulate the use of acoustically treated building materials and designs for residential dwelling units to meet acceptable interior noise level standards.

- amendments to the Provincial Health Code to address noise in a similar manner as the control of other undesirable aspects of the physical environment including air and water pollution, in order to ensure that acceptable interior noise levels are considered during the construction of residential dwelling units.

- amendments to the development regulations of the Provincial Planning Act in order for the municipality to incorporate traffic noise considerations into the land use planning process through the Edmonton Land Use Bylaw No. 5996.

- provincial cost sharing of the attenuation of urban traffic noise problem locations.

The following policy areas were identified under the jurisdiction of the Municipality:

- the urban design policy of the General Municipal Plan Bylaw No. 6000 to address urban traffic noise to allow Council, the administration, developers and the public to make decisions concerning the control or improvement of the general sound environment of the City. The incorporation of noise policies within the General Municipal Plan Bylaw No. 6000 will ensure a comprehensive approach to noise problems.

- the Edmonton Land Use Bylaw No. 5996 to be amended to address traffic noise standards, policies and guidelines to ensure that future residential development will be compatible with nearby traffic noise sources by: i) excluding typically incompatible residential land uses from traffic noise impacted areas and replacing them with noise compatible uses such as commercial, industrial, and some institutional and recreational land uses; ii) by requiring specific details of development design or construction to mitigate potential traffic noise incompatibilities including spatial separation, acoustical barriers, and architectural and acoustical construction techniques and; iii) by permitting special land use barrier techniques for orienting the outdoor amenity areas of residential dwelling units which enable noise insensitive site design.

- the Terms of Reference for Area Redevelopment Plans, Area Structure Plans and Area Redevelopment Plans to be amended to address traffic noise standards, policies and guidelines

and stipulate the consideration of traffic noise as a criterion for approving development and redevelopment plans, in order to ensure the implementation of the proposed amendments to the General Municipal Plan Bylaw No. 6000 and the Edmonton Land Use Bylaw No. 5996 amendments regarding traffic noise.

- the existing review of Truck Route System Bylaw No. 5990 consider traffic noise concerns in order to minimize the designation of truck routes adjacent to noise sensitive residential land uses, particularly those that are technically and/or economically impractical to attenuate.

- amendments to the existing Municipal Noise Abatement Bylaw No. 4110 to facilitiate enforcement of various individual noise problem sources.

- the adoption of a City policy regarding the municipal control of land for resolving extreme noise problems (70 dBA or greater) in order to effectively deal with excessive noise levels for situations where the use of physical barriers is not technically or economically possible, pending the availability of funding assistance from the Province.

- the current system of providing an economic allowance to property owners who are exposed to excessive levels of traffic noise to be amended to reflect a more accurate and equitable tax compensation for traffic noise impacted property.

- a 'buy-quiet' policy to give preference to the purchase of quieter vehicles by City departments in order to reduce the noise impacts of City owned vehicles.

3.4.2.2 Physical Techniques for Achieving the Noise Standards in Land Use and Transportation Planning

The second component of the implementation strategy examined the physical techniques that are available to architects, planners, developers and roadway engineers to achieve a reduction in noise levels for situations where changes in land use are proposed or where roadway construction or improvements are proposed.

Five physical noise attenuation techniques were examined as to their attenuation capability, economic aspects, public acceptability and the implementation process inherent for each technique. The techniques that were examined included: spatial separation, land use barriers, acoustical barriers, architectural techniques and acoustical construction techniques. The findings were not intended to provide complete criteria for selecting a solution to particular noise problems or act as a substitute for detailed acoustical design, rather its purpose was to assess the appropriateness of the various attenuation alternatives available for recomended use under the Land Use Bylaw.

Although the appropriate physical technique for a given situation will depend upon individual site conditions, noise control through land use planning techniques (spatial separation and land use barriers) are the most cost effective attenuation measures. To illustrate this point, a summary of these findings is provided below:

- The use of the spatial separation technique, as a measure to reduce outdoor noise levels, should be reviewed early in the planning process where flexibility in site planning can be exercised. Site planning can be used to provide

effective attenuation by the judicial location of land uses in relation to arterial roadways. The consideration of the spatial separation technique within the planning process should be encouraged as a viable, useful and aesthetically acceptable noise attenuation option. The present City policy requiring a 200' setback for development adjacent to designated truck routes or another form of attenuation to achieve the 60 dBA Ldn standard, is not considered an efficient use of the spatial separation technique as the setback distance should be flexible depending upon the site specific noise attenuation requirements.

- The use of land use barrier techniques to attenuate outdoor and indoor noise levels is also most beneficial when applied to a development project early in the planning process, when flexibility in site planning design can be exercised. The employment of intervening structures and the orientation of outdoor amenity areas as noise abatement techniques is economically efficient, as additional developable land is made available. The consideration of land use barrier techniques within the planning process and within the overall evaluation of alternative noise abatement measures is essential to ensure acceptable noise attenuation without excessive costs.

- Noise attenuation barriers should be considered as a secondary attenuation measure after other more cost-effective measures, as mentioned above, are considered for their noise abatement merits. However, there are situations, particularly within transportation planning, where the attenuation options are limited due to constraints imposed by existing land uses. For these situations excessive noise levels can only be mitigated by a noise attenuation barrier. Interim barrier design standards have been established by the municipality to ensure effective attenuation, aesthetics, maintenance, safety and structural durability.

- The use of architectural design techniques is the most appropriate method of achieving a satisfactory indoor sound environment. Developers are required to use architectural design techniques particularly within existing developed areas where there is limited space for implementing other forms of noise attenuation and for multi-storey residential buildings where other forms of attenuation are not technically feasible. In addition, this relatively low cost technique may be used to complement other noise attenuation measures. The objective interior noise level when applying this technique is 45 dBA Leq.

- The use of acoustical construction materials is also an effective noise attenuation technique for achieving a satisfactory indoor sound environment. Construction techniques will have to be evaluated for their potential to reduce the intrusion of traffic noise into the dwelling wherever residential areas are to be located adjacent to arterial roadways with existing or predicted exessive noise levels. The use of these materials is particularly effective in mitigating noise problems experienced by multi-storey residential buildings. The objective interior noise level when applying this technique is 45 dBA Leq.

3.4.2.3 Municipal Noise Abatement and Information Programs

The third component of the implementation strategy was the investigation of alternative program areas that the municipality could implement to reduce excessive traffic noise impacts on existing residential areas. Two program areas in particular were examined: a Noise Barrier Priorization Program and a Citizen Information Program.

The Noise Barrier Priorization Program identified the most critical residential areas requiring the installation of noise barriers. The study findings indicated that additional noise barriers are not required at this time for existing residential areas. This situation has occured as a result of the attenuation requirements for the most serious traffic noise problem locations being addressed by previous and current Functional Roadway Plans, Area Structure Plans and Neighbourhood Structure Plans. (The detailed analysis and results of this study are provided in Chapter 6 of UTNPS Stage II Volume III: Implementation Strategies (TSR/32/83).

Although it was determined that a noise barrier program was not required, there is a requirement for a Noise Monitoring Program for residential areas that are currently experiencing noise levels between 65 and 70 dBA Leq(24), to detect whether noise levels in the future reach an unacceptable level of 70 dBA Leq(24) or greater and for property tax relief assessment. It was found that an increase in noise levels can occur within a short period of time due to changes in land use, population growth and in the designation of truck routes.

The Noise Monitoring Program would select sites based on a computer noise model to determine problem locations that would be further tested using actual noise monitoring surveys. If the survey detects noise levels of 70 dBA Leq or greater, then the location would be recommended for the installation of a noise barrier, or in extreme situations, pending Provincial funding assistance, the municipal purchase of the affected property may be necessary.

The Citizen Information Program would be designed to inform the public of general principles of traffic noise and to give advise regarding cost effective noise attenuation measures that may be implemented to reduce the impact of noise upon the indoor sound environment. Various types of information would be disseminated including: i) an explanation of traffic noise principles; ii) advise to homeowners of appropriate noise attenuation measures to reduce indoor noise levels and possible grant funding assistance from the Federal Government; and iii) to explain the Municipal standards, policies and guidelines regarding not only traffic noise but other noise sources as well.

3.4.3 Summary of Implementation Strategies

In summary, these findings indicate a need to establish a noise level standard of 60 dBA Leq(24) with a discretionary range of up to 65 dBA, as this standard was found to be technically, economically and administratively feasible to implement City-wide. Furthermore, to ensure the implementation of this standard as well as generally reduce the amount of residential land adversely affected by traffic noise, there was a need identified to implement the various noise abatement alternatives that were investigated.

Strategies to formalize the adoption of the residential noise level standards and associated implementation measures identified in the Urban Traffic Noise Policy Study are detailed in the recommendations outlined in Chapter 4. There are no specific recommendations dealing with the individual physical attenuation techniques in this Chapter, except for acoustical barrier standards, however, the use of these techniques will be addressed within the amendments to the General Municipal Plan and Land Use Bylaw.

CHAPTER 4
RECOMMENDATIONS

4.1 INTRODUCTION

The recommendations focus on a multi-strategy approach to attenuating traffic noise to the recommended residential noise level standards, as it was recognized that solutions to noise problems vary depending upon specific noise sources, levels of noise, site conditions and legislation. An overview of required amendments to existing Federal, Provincial and Municipal policies and suggested municipal noise control programs by which the standards can be implemented, and the associated parties responsible for their implementation is presented. The recommendations:

- define acceptable residential noise levels standards and provide for the implementation of these standards.

- define the traffic noise attenuation responsibilities of the City, the developer and the resident.

- affect change with existing policy within senior and municipal levels of government to encourage, improve or regulate noise legislation.

- define the most effective attenuation techniques available to architects, planners, developers, and roadway engineers for achieving the noise standards for situations where changes in land use are proposed or where roadway construction or improvements are proposed.

- provide direction through the land use planning process for municipal decision makers, to ensure noise compatibility with residential land uses adjacent to arterial roadways in Edmonton.

- set up municipal noise control programs to help mitigate the traffic noise problems in existing residential areas.

A comprehensive and an economically, technically and administratively practical urban traffic noise abatement strategy would provide for the prevention of excessive noise levels in new residential areas and the attenuation of existing residential traffic noise problems. The current noise policy does not have an implementation strategy or means of integrating noise level standards in to the planning process that is required to ensure the reduction of the undesirable impacts of traffic noise on a City-wide basis. Therefore, in the recommendations there is an emphasis on amendments to existing policies and guidelines that offer solutions to the City-wide traffic noise problems, and to integrate these solutions in to the planning processes. It should be noted that, individually the recommendations may not have a significant effect on the overall urban sound environment, however, collectively, the recommendations contribute to achieving an acceptable urban sound environment.

The recommendations statements are listed according to the following categories:

i) Residential Noise Level Standards

ii) Amendments to Existing Senior Government Legislation
   - Vehicle noise emission regulations.
   - Tire standards and pavement design standard regulations.
   - Building code regulations.
   - Public Health Act regulations.
   - Planning Act regulations.
   - Provincial cost sharing of noise attenuation expenses.
   - Funding assistance for retrofit program through existing federal programs.
   - Formation of a Quiet Communities Directorate.

iii) Amendments to Existing Municipal Government Legislation

- General Municipal Plan.
- Land Use Bylaw.
- Terms of References for Area Redevelopment Plans, Area Structure Plans and Neighbourhood Structure Plans.
- Municipal Noise Abatement Bylaw.
- Property assessment.
- Traffic management.

iv) Municipal Noise Abatement and Information Programs

- Barrier Construction Program.
- Citizen Information Program.

v) Other Abatement Measures for Application by the Municipality

- 'Buy-Quiet' Program for purchase of City vehicles.
- Acoustical Barrier Standards.
- Municipal control of land.
- Railway Corridor Noise Study.

The following section is a list of the recommendation statements according to the above categories. The justification and further action required for the implementation of the recommendations is provided in Appendix I in the UTNPS Stage II Volume II: Evaluation and Selection of a Residential Noise Level Standard (TSR/31/83) and UTNPS Stage II Volume III: Implementation Strategies (TSR/32/83) which provide a more comprehensive review of the rationale used to formulate the recommendations.

4.2 RESIDENTIAL NOISE LEVEL STANDARDS

The intent of the following recommended residential noise level standards is to place the 60 dBA Leq(24) standard with a discretionary range of up to 65 dBA Leq(24) into the proper context recognizing the need to address different actors and situations. In addition, separate standards were required to address acceptable interior noise levels where there exists no outdoor amenity areas as well as indicate a threshold noise level whereby noise attenuation facilities for existing residential areas becomes cost effective. The data requirements and procedures for measuring and calculating traffic noise levels is outlined in Appendix IV.

4.2.1 That no new residential development less than 3 storeys be allowed adjacent to freeways and arterial roadways unless the developer proves to the satisfaction of the Transportation Management Department, that the projected noise level in outdoor amenity areas after applying attenuation measures will not exceed 60 dBA Leq(24), unless specific site characteristics, such as topography or existing land uses necessitate the consideration of relief from the standard. Under these circumstances, the attenuated noise level in outdoor amenity areas should be the lowest level technically and economically practicable with a maximum discretionary range up to 65 dBA Leq(24).

4.2.2 That where noise levels are projected to be within the discretionary range of 60 to 65 dBA Leq(24) in outdoor amenity areas, after the implementation of noise attenuation measures, the City, for any new residential development, shall require as a condition of approval that the developer inform prospective purchasers or renters of residential dwelling units which are affected by excessive noise by posting a sign in the affected building or by letter that reads:

"Purchasers are advised that despite the inclusion of noise attenuation features within the development area and/or within the individual building unit(s), noise levels may continue to be of concern, occassionally interfering with some activities of the dwelling occupants."

4.2.3 That, for residential development without outdoor amenity areas or for residential development of three storeys or more where the incident sound level at the facade of any dwelling units exceeds 60 dBA leq, the developer is to endeavor to achieve a projected interior noise level, after applying attenuation measures, of 45 dBA Leq(24) or less.

4.2.4 That the Transportation Management Department shall achieve a projected attenuated noise level as low as technically, administratively and economically practical below 65 dBA Leq(24) with an objective of achieving a noise level of 60 dBA Leq 24, where a freeway or arterial roadway are proposed to be built or upgraded through or adjacent to a developed residential area.

4.2.5 That existing residential sites with measured noise levels of 70 dBA Leq(24) or above in the outdoor amenity area be considered for noise attenuation by the City, provided the abatement measure will reduce the noise level by 10 dBA or greater, subject to the availability of funds and based on a priority index.

4.2.6 That residential property owners with existing residential dwelling units with measured noise levels less than 70 dBA Leq(24) who do not fall within the attenuation responsibilities of the City, be encouraged to improve the sound environment of their property through acoustically designed building improvements, at their own expense.

4.3 AMENDEMENTS TO SENIOR GOVERNMENT LEGISLATION AND PROGRAMS

The intent of the following recommendation statements is to encourage change with existing policies and programs of senior levels of government that can assist in the creation of an acceptable sound environment within Edmonton.

4.3.1 Vehicle Noise Emission Regulations

4.3.1.1 That City Council request the Minister of Transport Canada to investigate the feasibility of further reductions to the maximum allowable noise levels permitted for new vehicles (cars, trucks, buses and motorcycles) for the purpose of reducing vehicle noise levels at the source.

4.3.1.2 That City Council request the Minister of Alberta Transportation to consider the establishment of specific noise level limits by vehicle classification for incorporation within existing Municipal Noise Abatement Bylaws to ensure consistent province-wide standards.

4.3.1.3 That City Council request the Minister of Alberta Transportation to review the feasibility of a program of vehicle inspection for heavy motor vehicles, motorcycles and automobiles with respect to source noise, for implementation by the Province.

4.3.1.4 That City Council request the Minister of Supply and Services Canada and the Provincial Government to include a "buy quiet" preference as a criterion for use in the selection of vehicles under the jurisdiction of their respective Governments.

4.3.2 Tire Standards and Pavement Design Regulation

4.3.2.1 That City Council request the Minister of Transport Canada to research pavement design with the objective of reducing vehicular source noise and establishing appropriate regulations.

4.3.2.2 That City Council request the Minister of Transport Canada to continue and accelerate their research on tire standards with the objective of reducing vehicular source noise and establishing appropriate regulations.

4.3.2.3 That City Council request the Minister of Transport Canada through the Canadian Standards Association Tire Retread Committee to consider amendments to CSA Standards which would restrict the use of the pocket type retread tires on trucks with the objective of reducing vehicular source noise.

4.3.3 Building Code Regulations

4.3.3.1 That City Council request the Minister of the Provincial Department of Labour to investigate the feasibility of amending the Alberta Building Code to include acoustical guidelines, based on the CMHC Acoustical Insulation Factor Methodology, in order to ensure that noise abatement measures are included in the design and construction of residential dwelling units, schools, and hospitals located adjacent to major arterial roadways.

4.3.3.2 That City Council request the National Research Council of Canada to investigate the feasibility of amending the National Building Code to include acoustical guidelines, based on the CMHC Acoustical Insulation Factor Methodology,

for the purpose of ensuring that noise abatement measures are included in the design and construction of residential dwelling units, schools and hospitals located adjacent to major arterial roadways.

4.3.4 Health Regulations

4.3.4.1 That City Council request the Provincial Board of Health to investigate the feasibility of amending the Public Health Act to include a maximum allowable noise level for the interior of residential dwelling units for implementation by the Province in order to ensure noise is considered along with other health concerns in the design and construction of residential dwelling units.

4.3.5 Planning Act Legislation

4.3.5.1 That City Council request the Minister of Alberta Municipal Affairs to amend Sections 69, 77 and 92 of the Planning Act R.S.A. 1980, that would provide the necessary mandate for the municipality to use the Municipal Land Use Bylaw No. 5996 to control and regulate noise attenuation requirements for the development of residential land adjacent to arterial roadways and freeways; and to enter into agreements with developers to install or pay for the installation of noise attenuation devices or design alternatives that are necessary to achieve an acceptable noise level for new residential development.

4.3.6 Provincial Cost Sharing of Noise Attenuation Expenses

4.3.6.1 That City Council request the Minister of Alberta Transportation to consider the provision of financial assistance in implementing a noise barrier priorization

program and for land purchase, as solutions to noise problems, to the same extent that it shares in the cost of constructing provincial highways in municipalities.

4.3.7 Funding Assistance for Retrofitting Existing Residential Dwelling Units

4.3.7.1 That City Council request that the Minister of Canada Mortgage and Housing Corporation to consider the provision of funding assistance for property owners that are exposed to traffic noise levels greater than 60 dBA Leq(24) along arterial roadways, through the Canada Home Renovation Plan (CHRP), the Residential Rehabilitation Assistance Program (RRAP), the Canada Home Insulation Program (CHIP) or another appropriate existing government grant program, to aid residents in undertaking the necessary acoustical modifications to affected dwelling units.

4.3.8 Formation of a Quiet Communities Directorate

4.3.8.1 That City Council request the Minister of Municipal Affairs to consider the establishment of a 'Quiet Communities Directorate' to provide leadership in achieving a quiet environment in Aberta.

4.4 AMENDMENTS TO MUNICIPAL LEGISLATION

The intent of the following recommendation statements is to affect change with existing policies and programs of the municipality that can ensure the creation of an acceptable sound environment; and to integrate the consideration of traffic noise into the overall comprehensive planning process. It should be noted that the proposed amendments to the Land Use Bylaw and the Terms of References for Area Redevelopment Plans, Area Structure Plans and Neighbourhood Structure Plans, cannot be brought into

effect until the previously stated amendments to enabling legislation within the Planning Act R.S.A 1980, are made that would allow the Municipality to impose the provision of noise attenuation at the subdivision and redistricting stages of development. Therefore, the recommendations concerning the Land Use Bylaw cannot be acted upon by the Planning Department until approval is granted for proposed changes to the Planning Act by the Alberta Planning Board.

4.4.1 General Municipal Plan Bylaw No. 6000

4.4.1.1 That City Council direct the Planning Department to amend the General Municipal Plan Bylaw No. 6000, Urban Design Chapter, to include objective and policy statements dealing with traffic noise in order to promote the consideration of noise abatement using design elements including spatial separation, land use barriers, acoustical barriers, architectural design techniques and acoustical construction materials, in the preparation and review of residential plans and development proposals.

4.4.1.2 That City Council direct the Planning Department to include land use planning guidelines and standards for noise control within the proposed Urban Design Guidelines Handbook to assist in the preparation of the urban design component of District Plans and other statutory plans, and in the review of redistricting and development applications adjacent to arterial roadways.

4.4.1.3 That City Council direct the Planning Department to include land use planning guidelines and standards for noise control within the proposed Handbook of Urban Design Objectives, Policies and Guidelines for Newly Developed Areas, that is to be used in the preparation of Area and Neighbourhood Structure Plans and plans of subdivision and in the review and approval processes for these plans.

4.4.1.4 That City Council direct the Planning Department to encourage innovative residential projects which demonstrate opportunities to create an acceptable urban sound environment using land use planning techniques.

4.4.2 Land Use Bylaw No. 5996

4.4.2.1 That City Council direct the Planning Department, pending approval of the proposed amendments to enabling legislation within the Planning Act R.S.A. 1980, to amend the text of the Land Use Bylaw No. 5996, Section 16 Special Information Requirements, to include a traffic noise impact study as part of the submission of a development proposal when it involves residential plans of subdivisions, redistricting and site plans adjacent to an arterial roadway or freeway.

4.4.2.2 That City Council direct the Planning Department, pending approval of the proposed amendments to enabling legislation within the Planning Act, R.S.A. 1980, to amend the text of the Land Use Bylaw No. 5996, Section 17, to require as a condition of issuing a development permit, for residential development abutting an arterial roadway, that an applicant enter into an agreement which shall be attached to and form part of such permit, to provide the attenuation measures necessary to achieve the residential noise level standards.

4.4.3 Terms of References for Area Redevelopment Plans, Area Structure Plans and Neighbourhood Structure Plans

4.4.3.1 That City Council direct the Planning Department, pending approval of the proposed amendments to enabling legislation within the Planning Act, R.S.A. 1980, to amend

the Terms of Reference for Area Redevelopment Plans within the Environmental Impact Assessment section, to provide for a review of all noise sensitive residential land uses adjacent to arterial roadways in order to determine either a more compatible land use, redevelopment guidelines for residential land uses that require compliance with the residential noise level standards and/or physical attenuation measures that may be taken to mitigate the noise problem.

4.4.3.2 That City Council direct the Planning Department, pending approval of the proposed amendments to enabling legislation within the Planning Act, R.S.A. 1980, to amend the Terms of Reference for Area Structure Plans to include under Section 10, Support Materials, a request for a preliminary analysis of the compatibility of the proposed residential land use adjacent to existing or proposed arterial roadways, and an indication of any measures that will be employed to ensure compliance with the residential noise level standards.

4.4.3.3 That City Council direct the Planning Department, pending approval of the proposed amendments to enabling legislation within the Planning Act, R.S.A. 1980, to amend the Terms of Reference for Neighbourhood Structure Plans to include within the environmental impact analysis requirements, a detailed explanation of measures that will be employed to achieve compatibility of residential land uses adjacent to existing or proposed arterial roadways to ensure compliance with the residential noise level standards.

4.4.1.4 That City Council direct the Planning Department to encourage innovative residential projects which demonstrate opportunities to create an acceptable urban sound environment using land use planning techniques.

4.4.2 Land Use Bylaw No. 5996

4.4.2.1 That City Council direct the Planning Department, pending approval of the proposed amendments to enabling legislation within the Planning Act R.S.A. 1980, to amend the text of the Land Use Bylaw No. 5996, Section 16 Special Information Requirements, to include a traffic noise impact study as part of the submission of a development proposal when it involves residential plans of subdivisions, redistricting and site plans adjacent to an arterial roadway or freeway.

4.4.2.2 That City Council direct the Planning Department, pending approval of the proposed amendments to enabling legislation within the Planning Act, R.S.A. 1980, to amend the text of the Land Use Bylaw No. 5996, Section 17, to require as a condition of issuing a development permit, for residential development abutting an arterial roadway, that an applicant enter into an agreement which shall be attached to and form part of such permit, to provide the attenuation measures necessary to achieve the residential noise level standards.

4.4.3 Terms of References for Area Redevelopment Plans, Area Structure Plans and Neighbourhood Structure Plans

4.4.3.1 That City Council direct the Planning Department, pending approval of the proposed amendments to enabling legislation within the Planning Act, R.S.A. 1980, to amend

the Terms of Reference for Area Redevelopment Plans within the Environmental Impact Assessment section, to provide for a review of all noise sensitive residential land uses adjacent to arterial roadways in order to determine either a more compatible land use, redevelopment guidelines for residential land uses that require compliance with the residential noise level standards and/or physical attenuation measures that may be taken to mitigate the noise problem.

4.4.3.2 That City Council direct the Planning Department, pending approval of the proposed amendments to enabling legislation within the Planning Act, R.S.A. 1980, to amend the Terms of Reference for Area Structure Plans to include under Section 10, Support Materials, a request for a preliminary analysis of the compatibility of the proposed residential land use adjacent to existing or proposed arterial roadways, and an indication of any measures that will be employed to ensure compliance with the residential noise level standards.

4.4.3.3 That City Council direct the Planning Department, pending approval of the proposed amendments to enabling legislation within the Planning Act, R.S.A. 1980, to amend the Terms of Reference for Neighbourhood Structure Plans to include within the environmental impact analysis requirements, a detailed explanation of measures that will be employed to achieve compatibility of residential land uses adjacent to existing or proposed arterial roadways to ensure compliance with the residential noise level standards.

4.4.4 Municipal Noise Abatement Bylaw

4.4.4.1 That City Council adopt the revised Municipal Noise Abatement Bylaw No. 4110 that has been prepared as a separate report for reading, in order to facilitate the enforcement of individual source noise problems and in particular vehicle sources of noise affecting the sound environment of the City.

4.4.5 Property Assessment

4.4.5.1 That City Council direct the Assessment Department to adopt a more accurate and equitable tax compensation procedure for traffic noise impacted property, using actual noise monitoring surveys.

4.4.5.2 That City Council direct the Transportation Management Department to establish and maintain a Noise Monitoring Program that would predict residential noise levels adjacent to major arterial roadways and freeways, with 1983 acting as the initial year of commencement.

4.4.6 Traffic Management

4.4.6.1 That City Council direct the Transportation Management Department to address traffic noise considerations in their current review of the existing Truck Route System Bylaw No. 5990, in order to minimize noise impacts on residential areas.

4.5 MUNICIPAL NOISE ABATEMENT AND INFORMATION PROGRAMS

4.5.1 Barrier Priorization Program

4.5.1.1 That City Council adopt a noise barrier priorization program whereby existing residential locations with reversed frontage, adequate open space and experiencing noise levels of 70 dBA Leq(24) or above be considered for noise barrier attenuation subject to ranking according to the proposed Noise Monitoring Program and the availability of funds.

4.5.1.2 That City Council direct the Engineering Department to establish a separate Special Capital Project within the 5 and 10 Year Roadway and Transit Improvement Program setting out funding for identified noise attenuation projects, and annually, as part of the Capital Budget deliberations, establish a barrier priorization program in conjunction with the priorities of the total capital budget program, according to a priority index or as required, until the needs are met.

4.5.2 Citizen Information Program

4.5.2.1 That the Transportation Management Department establish a Citizen Information Program for the purpose of explaining the municipal traffic noise policies, programs and also abatement measures that may be employed by individual homeowners to improve their indoor sound environment.

4.6 OTHER ABATEMENT MEASURES FOR APPLICATION BY THE MUNICIPALITY

4.6.1 Purchase of City Vehicles

4.6.1.1 That City Council direct the Central Supply and Services and Transit Departments to address within the specifications developed for the purchase of City vehicles, the noise levels and limits of the equipment, and specify noise level limits in dBA, taking into consideration the type of vehicle and current technology.

4.6.2 Acoustical Barrier Standards

4.6.2.1 That City Council direct the Engineering Department to prepare a Barrier Design Standards Manual for the purpose of ensuring that barrier noise attenuation facilities are effective, easily maintained, durable and aesthetically acceptable, and in the interim to continue to use the existing list of design guidelines as presented in Appendix V.

4.6.3 Municipal Control of Land

4.6.3.1 That City Council direct the Transportation Management Department to attenuate residential noise problems through the municipal control of land, where residential property adjacent to arterial roadways is experiencing noise levels in excess of 70 dBA Leq(24) in the outdoor amenity area and cannot be attenuated by a standard noise barrier due to technical constraints, pending the availability of funding assistance from the Province.

4.6.3.2 That City Council direct the Planning Department to consider redistricting residential property, adjacent to arterial roadways, that is experiencing traffic noise

levels greater than 65 dBA Leq(24) in the outdoor amenity area, to a more compatible land use in conjunction with existing and proposed Area Redevelopment Plans, upon concurrance with a majority of the affected property owners.

4.6.4 Future Noise Studies

4.6.4.1 That City Council direct the Transportation Management Department to undertake a study regarding land use policies and associated noise standards for residential land uses adjacent to railway corridors.

APPENDIX I

MATRIX OF RECOMMENDATIONS, RATIONALE AND ACTION TO BE TAKEN

This appendix summarizes the rationale and the required action to be taken for the implementation of each study recommendation. The key responsible parties for the implementation of the recommendations is also indicated, and is further defined in Appendix II.

REFERENCE NUMBER Vol.I Vol. II Vol.III	RECOMMENDATION	RATIONALE	ACTION REQUIRED
4.2	RESIDENTIAL NOISE LEVEL STANDARDS		
4.2.1	That no new residential development less than 3 storeys be allowed adjacent to freeways and arterial roadways unless the developer proves to the satisfaction of the Transportation Management Department, that the projected noise level in outdoor amenity areas after applying attenuation measures will not exceed 60 dBA Leq (24), unless specific site characteristics, such as topography or existing land uses necessitate the consideration of relief from the standard. Under these circumstances, the attenuated noise level in outdoor amenity areas should be the lowest level technically and economically practicable with a maximum discretionary range up to 65 dBA Leq (24).	To ensure new residential development less than 3 storeys adjacent to arterial roadways is adequately protected from traffic noise throughout the City, a noise level standard of 60 dBA Leq (24) is required. The selection of the standard was based on the following evaluation criteria: - State-of-the Art review of noise standards and policies in use elsewhere in North America. - A review of health and welfare impacts, and economic, technical and administrative constraints. The range recognizes the need for flexibility in order to address technical and economic constraints.	The development industry ensure that the noise level standards are addressed in planning residential projects and in the submission for their approval.
4.2.2	That were noise levels are projected to be within the discretionary range of 60 to 65 dBA Leq (24) in outdoor amenity areas, after the implementation of noise attenuation measures, the City, for any new residential development, shall require as a condition of approval that the developer inform prospective purchasers or renters of residential dwelling units which are affected by excessive noise by posting a sign in the affected building or by letter that reads: "Purchasers are advised that despite the inclusion of noise attenuation features within the development	To warn prospective home purchasers or renters, and to negate the City from liability, the public must be informed of new residential dwelling units that are affected by excessive noise levels.	The development industry ensure that prospective purchasers or renters are informed of potential noise problems.

REFERENCE NUMBER Vol.I Vol. II Vol.III	RECOMMENDATION	RATIONALE	ACTION REQUIRED
	area and/or within the individual building unit(s), noise levels may continue to be of concern, occasionally interfering with some activities of the dwelling occupants".		
4.2.3	That,for residential development without outdoor amenity areas, or for residential buildings three storeys or more where the incident sound level at the facade of any dwelling unit exceeds 60 dBA Leq, the developer is to endeavor to achieve a projected interior noise level, after applying acceptable attenuation measures, of 45 dBA Leq (24) or less.	To ensure acceptable interior noise levels for high rise residential buildings where there is no outdoor amenity area from which traffic noise can be measured, as in the case of multi-storey residential buildings, and where architectural or acoustical building materials are used, an objective interim indoor noise level standard of 45 DBA will apply until appropriate indoor standards are established by the Provincial Board of Health.	The development industry address acceptable indoor noise levels where for residential development applications of 3 storeys or more.
4.2.4	That the Transportation Management Department shall achieve a projected attenuated noise level as low as technically, administratively and economically practical below 65 dBA Leq (24) with the objective of achieving a noise level of 60 dBA Leq (24), where a freeway or arterial roadway are proposed to be built or upgraded through or adjacent to a developed residential area.	To ensure that future transportation roadway planning through or adjacent to an existing residential area, be designed to achieve the objective attenuated noise level or as low as technically administratively and economically practicable. To protect existing residential sites adjacent to arterials subject to traffic noise.	The Transportation Management Department integrate the residential noise level standard into the transportation planning process.
4.2.5	That existing residential sites with measured noise levels of 70 dBA Leq (24) or above in the outdoor amenity area be considered for noise attenuation by the City provided the	The use of physical noise attenuation measures for abating noise problems in existing residential areas is not cost-effective unless a 10 dBA noise	The Transportation Management Department examine the feasibility of noise attenuation for these residential sites

REFERENCE NUMBER Vol.I Vol. II Vol.III	RECOMMENDATION	RATIONALE	ACTION REQUIRED
	abatement measure will reduce the noise level by 10 dBA or greater and subject to the availability of funds and based on a priority index.	reduction is achieved.	within the context of a Noise Barrier Priorization Program.
4.2.6	That residential property owners with existing residential dwelling units with measured noise levels less than 70 dBA Leq (24) who do not fall within the attenuation responsibilities of the City, be encouraged to improve the sound environment, of their property through acoustically designed building improvements at their own expense.	It is not technically, economically and administratively feasible to reduce all residential locations to acceptable noise levels by the municipality.	The resident is voluntarily responsible for noise attenuating action. The Transportation Management Department is to establish a Public Information Program as well as negotiate possible grant funding assistance under existing CMHC home improvement programs.
4.3	AMENDMENTS TO EXISTING SENIOR GOVERNMENT LEGISLATION		
4.3.1	Vehicle Noise Emission Regulations		
4.3.1.1	That City Council request the Minister of Transport Canada to investigate the feasibility of further reductions to the maximum allowable noise levels permitted for new vehicles (cars, trucks, buses and motorcycles) for the purpose or reducing vehicle noise levels at the source.	Reduced individual vehicle noise emissions will contribute to an overall reduction of traffic noise. Transport Canada's current activities and priorities support this recommendation.	The Transportation Management Department coordinate, through Executive Services, a request to Transport Canada to undertake the recommended investigation.
4.3.1.2	That City Council request the Minister of Alberta Transportation to consider the establishmentof specific noise level limits by vehicle classification for incorporation within existing Municipal Noise Abatement Bylaws to ensure consistent province-wide standards.	Specific individual vehicle noise limits will contribute to an overall reduction in traffic noise levels and overcome the current problem experienced by truckers with respect to variable noise regulations.	The Transportation Management Department coordinate through Executive Services, a request to Alberta Transportation to consider the feasibility of implementing the recommendation.

REFERENCE NUMBER Vol.I Vol. II Vol.III	RECOMMENDATION	RATIONALE	ACTION REQUIRED
4.3.1.3	That City Council request the Minister of Alberta Transportation to review the feasibility of a program of vehicle inspection for heavy motor vehicles, motorcycles and automobiles with respect to source noise, for implementation by the Province.	To ensure compliance with vehicle noise emission regulations and to ensure the proper maintenance of existing vehicle fleet.	The Transportation Management Department coordinate through Executive Services, a request to Alberta Transportation to consider the feasibility of implementing the recommendation.
4.3.1.4	That City Council request the Minister of Supply and Services Canada and the Provincial Government to include a "buy quiet" preference as a criterion for use in the selection of vehicles under the jurisdiction of their respective Governments.	A "buy quiet" preference will contribute to reduced noise levels and be indicative of the City's seriousness and sincerity with regard to noise problems, and encourage motor vehicle manufacturers to produce quieter vehicles.	The Transportation Management Dept. coordinate through Executive Services, a request to the Federal and Provincial Governments to include noise emissions as a criterion in vehicle selection.
4.3.2	Tire Standards and Pavement Design Regulation		
4.3.2.1	That City Council request the Minister of Transport Canada to research pavement design with the objective of reducing vehicular source noise and establishing appropriate regulations.	Pavement design is an important aspect in the generation of noise from tire/roadway contact that has the potential to reduce vehicle noise.	The Transportation Management Dept. coordinate through Executive Services, a request to Transport Canada to undertake the recommended research.
4.3.2.2	That City Council request the Minister of Transport Canada to continue and accelerate their research on tire standards with the objective of reducing vehicular source noise and establishing appropriate regulations.	Tire tread type is a major factor in the generation of traffic noise that may be designed to reduce vehicle noise.	The Transportation Management Dept. coordinate through Executive Services, a request to Transport Canada to undertake the recommended research.
4.3.2.3	That City Council request the Minister of Transport Canada through the Canadian Standards Association Tire Retread Committee to consider amendments to CSA standards which would restrict the use of the pocket type retread tires on trucks with the objective of reducing vehicular noise.	The pocket retread tires contributes more to urban traffic noise than any other tire tread type and should be restricted from use within urban areas.	The Transportation Management Dept. coordinate through Executive Services, a request to Transport Canada to consider the restricted use of this type of tire.

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4.3.3.	Building Code Regulations.		
4.3.3.1	That City Council request the Minister of the Provincial Department of Labour to investigate the feasibility of amending the Alberta Building Code to include acoustical guidelines, based on the CMHC Acoustical Insulation Factor Methodology, in order to ensure that noise abatement measures are included in the design and construction of residential dwelling units, schools, and hospitals located adjacent to major arterial roadways.	The Alberta Building Code should: - address interior noise levels in order to ensure acceptable interior sound environments are provided for through building code regulations. - apply the CMHC Acoustical Insulation Factor methodology for the determination of adequate interior sound insulation as it is the most effective method available at this time.	The Transportation Management Dept. coordinate through Executive Services, a request to the Alberta Department of Labour, Building Standards Division, to examine the feasibility of amending the Alberta Building Code.
4.3.3.2	That City Council request the National Research Council of Canada to investigate the feasibility of amending the National Building Code to include acoustical guidelines, based on the CMHC Acoustical Insulation Factor Methodology, for the purpose of ensuring that noise abatement measures are included in the design and construction of residential dwelling units, schools and hospitals located adjacent to major arterial roadways.	The National Building Code should: -address interior noise levels in order to ensure acceptable interior sound environments are provided for through building code regulations - apply the CMHC Acoustical Insulation Factor methodology for the determination of adequate interior sound insulation as it is the most effective method available at this time.	The Transportation Management Dept. coordinate through Executive Services, a request to the National Research Council, Associate Committee for the National Building Code, to examine the feasibility of amending the National Building Code.
4.3.4	Health Regulation		
4.3.4.1	That City Council request the Provincial Board of Health to investigate the feasibility of amending the Public Health Act to include a maximum allowable noise	The inclusion of guidelines regarding allowable noise levels for the interior of residential dwelling units will ensure habitable living	The Transportation Management Dept. coordinate through Executive Services, a request to the Provincial Board of Health to examine the

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	level for the interior of residential dwelling units, for implementation by the Province, in order to ensure noise is considered along with other health concerns in the design and construction of residential dwelling units.	environment.	feasibility of implementing the recommendation.
4.3.5	Planning Act Legislation		
4.3.5.1	That City Council request the Minister of Alberta Municipal Affairs to amend Sections 69, 77 and 92 of the Planning Act R.S.A. 1980, that would provide the necessary mandate for a municipality to use the Municipal Land Use Bylaw No. 5996 to control and regulate noise attenuation requirements for the development of residential land adjacent to arterial roadways and freeways; and to enter into agreements with developers to install or pay for the installation of noise attenuation devices or design alternatives that are necessary to achieve an acceptable noise level for new residential development.	The effective application of a residential noise standard requires: - municipal authority to regulate noise attenuation requirements of residential land adjacent to arterial roadways, - the authority to enter into agreements with developers to apply noise attenuation techniques or design alternatives where necessary.	The Transportation Management Dept. coordinate through Executive Services, and with the assistance of the City of Edmonton Law Dept. and the City of Calgary Tranportation Dept., a request to Alberta Municipal Affairs to make the recommended amendments to the Planning Act.
4.3.6	Provincial Cost Sharing of Noise Barrier Expenses		
4.3.6.1	That City Council request that the Minister of Alberta Transportation to consider the provision of financial assistance in implementing a noise barrier priorization program or for land purchase as solutions to noise problems, to the same extent that it shares in the cost of constructing provincial highways in municipalities.	The provision of noise attenuation is in a majority of instances, usually required with the construction of provincially funded roadway projects within the City and therefore should be considered in the overall costs of the projects.	The Transportation Management Department coordinate through Executive Services, a request to Alberta Transportation to consider the provision of financial assistance for the implementation of a noise attenuation program.

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		Though retrofit is quite effective, it is an extremely expensive approach and should be used only where truck routes or provincial highways cut through existing residential areas and create major noise problems. Though a change of use or an increase in density holds excellent promise of a long-term economic payoff, the so-called "up-front" costs are extremely high. This is because a number of properties must be purchased over a long period of time with potential problems of holdout or speculation, designs must be developed for the new uses that will replace those fronting on the noisy arterial, and the project must eventually be constructed. Such a project could take several years. However, one of the reasons that development is a preferred alternative is because the potential returns from the upgrading of land uses should be sufficient to cover the cost of the property and the special sound treatment required. Therefore the province should make low-cost loans available so that the municipality is not inhibited by a shortage of funds from proceeding with redevelopment as a solution to noise problems, where this is the most cost-efficient solution to the problem.	

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4.3.7	Funding Assistance for Retrofitting Residential Dwelling Units		
4.3.7.1	That City Council request the Minister of Canada Mortgage and Housing Corporation to consider funding assistance for property owners that are exposed to traffic noise levels greater than 60 dBA Leq (24) along arterial roadways through the Canada Home Renovation Plan (CHRP), the Residential Rehabilitation Assistance Program (RRAP), the Canada Home Insulation Program (CHIP) or another appropriate existing government grant program, to aid residents in undertaking the necessary acoustical modifidcations to affected dwelling units.	A request for CMHC funding is appropriate as: - it would cost the City in excess of $8,000,000 excluding administrative cost, to retrofit residential dwelling units along arterial roadways in the City which is an excessive economic burden. - CMHC has existing grant funding programs that are designed to improve the living environment of existing residential dwelling units.	The Transportation Management Department coordinate through Executive Services, a request to Canada Mortgage and Housing Corporation to consider the possibility of providing funding assistance for acoustical modifications for dwellings through existing home improvement programs.
4.3.8	Formation of a Quiet Communities Directorate		
4.3.8.1	That City Council request the Minister of Municipal Affairs to consider the establishment of a 'Quiet Communities Directorate' to provide leadership in achieving a quiet environment in Alberta.	An important aspect to creating quiet communities is to establish an agency whose sole responsibility would be noise control. The functions of this agency, identified as the Quiet Communities Directorate, would be: - to develop a core of technical expertise about noise, its nature, hazards, and control, that would be available to the provincial government departments, municipalities, and the public at large. - to develop special programs to achieve quiet communities; for	The Environment Council of Alberta, with support from the Transportation Management Dept, initiate the formation of such an agency.

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		example, through education, economic programs, and development of a model municipal noise control by-law. - to liaise and co-ordinate noise concerns among jurisdictions and departments.	
4.4	AMENDMENTS TO EXISTING MUNICIPAL LEGISLATION		
4.4.1	General Municipal Plan		
4.4.1.1	That City Council direct the Planning Department to amend the General Municipal Plan Bylaw No. 6000, Urban Design Chapter, to include objective and policy statements dealing with traffic noise in order to promote the consideration of noise abatement using design elements including spatial separation; land use barriers, acoustical barriers, architectural design techniques and acoustical construction materials, in the preparation and review of residential plans and development proposals.	General Municipal Plan amendments are necessary: - to facilitate decisions concerning the control and improvement of the general sound environment - to ensure developers are aware of the context into which they will be placing their development projects with respect to traffic noise concerns. - to ensure a comprehensive, rather than a piece-meal approach to noise problems. - to authorize the application of the physical noise attenuation mechanisms noted.	The Transportation Management Dept. with the assistance of the Planning Dept., prepare and attain approval of the GMP amendments and subsequently implement the amendments.
4.4.1.2	That City Council direct the Planning Department to include land use planning guidelines and standards for noise control within the proposed Urban Design Guidelines Handbook to assist in the preparation of the urban	The consideration of noise control guidelines and standards within District Plans and other statutory plans will reduce residential noise problem locations as redeve-	The Transportation Management Dept. with the assistance of the Planning Dept., prepare and attain approval of the GMP amendments and subsequently

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	design component of District Plans and other statutory plans, and in the review of redistricting and development applications adjacent to arterial roadways.	velopment occurs.	implement the amendments.
4.4.1.3	That City Council direct the Planning Department to include land use planning guidelines and standards for noise control within the proposed Handbook of Urban Design Objectives, Policies and Guidelines for Newly Developed Areas, that is to be used in the preparation of Area and Neighbourhood Structure Plans and plans of subdivision and in the review and approval processes for these plans.	The consideration of noise control guidelines and standards during the preparation of the stated plans and in the review and approval process for the plans will minimize the occurrance of new noise problem locations.	The Transportation Management Dept. with the assistance of the Planning Dept., prepare and attain approval of the GMP amendment and subsequently implement the amendment.
4.4.1.4	That City Council direct the Planning Department to encourage innovative residential projects which demonstrate opportunities to create an acceptable urban sound environment using land use planning techniques.	Innovative residential projects will allow flexibility in the use of physical noise abatement mechanisms to achieve an acceptable sound environment that otherwise may not be technically or economically possible.	The Planning Department to implement the recommendation where feasible.
4.4.2	Land Use Bylaw No. 5996		
4.4.2.1	That City Council direct the Planning Dept. pending approval of the proposed amendments to enabling legislation within the Planning Act R.S.A. 1980, to amend the text of the Land Use Bylaw No. 5996, Section 16 Special Information Requirements to include a traffic noise impact study as part of the submission of a development proposal when it involves residential plans of subdivisions, redistricting and site plans adjacent to an arterial roadway	The amendments to the Land Use Bylaw are necessary: - to integrate traffic noise standards, policies and guidelines into the land use planning process. - to guide noise sensitive land uses away from roadway noise sources and encourage non-sensitive land	The Transportation Management Dept. with assistance from the Planning Dept., prepare and attain approval and subsequently implement the required amendment.

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			or freeway.	uses or where this is not possible, to ensure measures are included in residential development projects to reduce the effects of traffic noise to meet the standards.	
4.4.2.2			That City Council direct the Planning Department pending approval of the amendments to enabling legislation within the Planning Act R.S.A. 1980, to amend the text of the Land Use Bylaw No. 5996, Section 17 to require as a condition of issuing a development permit, for residential development abutting an arterial roadway, that an applicant enter into an agreement which shall be attached to and form part of such permit, to provide the attenuation measures necessary to achieve the residential noise level standards.	The amendment to the Land Use Bylaw is necessary to ensure specific requirements regarding the details of development design or construction are addressed for the purpose of mitigating potential traffic noise incompatibilities by entering into an agreement with the City and the the applicant.	The Transportation Management Dept. with assistance from from the Planning Dept., prepare and attain approval and subsequently implement the required amendment.
4.4.3			Terms of References for Area Redevelopment Plans, Area Structure Plans and Neighbourhood Structure Plans.		
4.4.3.1			That City Council direct the Planning Department to amend the Terms of Reference for Area Redevelopment Plans, pending approval of the proposed amendments to enabling legislation within the Planning Act, R.S.A. 1980, within the Environmental Impact Assessment section, to provide for a review of all noise sensitive residential land uses adjacent to arterial roadways in order to determine either a more compatible land use, redevelopment guidelines for residential land uses that require compliance with the residential noise level	The amendment is required: - to encourage redistricting of noise impacted residential land uses to more compatible land uses within the context of Area Redevelopment Plans. - to ensure implementation of the proposed General Municipal Plan and Land Use Bylaw Amendments regarding traffic noise standards, policies and guidelines.	The Transportation Management Dept. with assistance from the Planning Dept., prepare and implement the amendments to the Terms of Reference for Area Redevelopment Plans as recommended.

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	standard and/or physical attenuation measures that may be taken to mitigate the noise problem.		
4.4.3.2	That City Council direct the Planning Dept. pending approval of the proposed amendments to enabling legislation within the Planning Act, R.S.A. 1980, to amend the Terms of Reference for Area Structure Plans, to include under Section 10, Support Materials, a request for a preliminary analysis of the compatibility of the proposed residential land use adjacent to existing or proposed arterial roadways, and an indication of any measures that will be employed to ensure compliance with the residential noise level standards.	The amendment is required: - to include the consideration of traffic noise at an early stage of planning and to use the noise standards as one of the criteria for approving Area Structure Plans. - to ensure implementation of the proposed General Municipal Plan and Land Use Bylaw Amendments regarding traffic noise, standards, policies and guidelines.	The Transportation Management Dept. with assistance from the Planning Dept., prepare the amendments to the Terms of Reference for Area Structure Plans as recommended.
4.4.3.3	That City Council direct the Planning Department pending approval of the proposed amendments to enabling legislation within the Planning Act, R.S.A. 1980, to amend the Terms of Reference for Neighbourhood Structure Plans, to include within the environmental impact analysis requirements, a detailed explanation of measures that will be employed to achieve compatibility of residential land uses adjacent to existing or proposed arterial roadways in order to ensure compliance with the residential noise level standards.	The amendment is required: - to include the consideration of traffic noise at an early stage of planning and to use the noise standards as one of the criteria for approving Neighbourhood Structure Plans. - to ensure implementation of the proposed General Municipal Plan and Land Use Bylaw Amendments regarding traffic noise standards, policies and guidelines.	The Transportation Management Dept. with assistance from the Planning Dept., prepare and implement the amendments to the Terms of Reference for Neighbourhood Structure Plans as recommended.
4.4.4	Municipal Noise Abatement Bylaw	The amendments are required:	

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4.4.4.1	That City Council adopt the revised Municipal Noise Abatement Bylaw No. 4110 that has been prepared as a separate report for reading, in order to facilitate the enforcement of individual source noise problems and in particular vehicle sources of noise affecting the sound environment of the City.	- to facilitate the regulation and enforcement of noise emission levels. - to facilitate the regulation and enforcement of other sources of noise.	The Police, Bylaw Enforcement and Health Departments enforce the revised Municipal Noise Abatement Bylaw upon approval by City Council.
4.4.5	Property Assessment		
4.4.5.1	That City Council direct the Assessment Department to adopt a more accurate and equitable tax compensation procedure for traffic noise impacted property, using actual noise monitoring surveys.	The current system of subjectively determining economic allowances for property owners on the basis of exposure to noise, be amended to reflect a more accurate and equitable tax compensation system using actual noise measurement data.	The Assessment Department to review the economic allowance system as recommended.
4.4.5.2	That City Council direct the Transportation Management Department to establish and maintain a Noise Monitoring Program that would predict noise levels in residential areas adjacent to major arterial roadways and freeways with 1983 acting as the initial year of commencement.	The data obtained from the Noise Monitoring Program would provide the necessary information for a more accurate and equitable tax compensation procedure as well as identify priority attenuation locations for the Barrier Priorization Program.	The Material and Testing of the Engineering Department to establish the Noise Monitoring Program as recommended.
4.4.6	Traffic Management		
4.4.6.1	That City Council direct the Transportation Management Department to address traffic noise considerations in their current review of the existing Truck Route System Bylaw 5990, in order to minimize noise impacts on residential areas.	Residential land use incompatibility can be minimized if truck routes are located away from noise sensitive land uses or where roadways are not able to be attenuated.	The Transportation Management Dept. ensure that traffic noise is addressed in the current Provincial Review of Municipal Truck Routes.

REFERENCE NUMBER Vol.I	Vol. II	Vol.III	RECOMMENDATION	RATIONALE	ACTION REQUIRED
4.5			MUNICIPAL NOISE ABATEMENT AND INFORMATION PROGRAMS		
4.5.1			Barrier Priorization Program		
4.5.1.1			That City Council adopt a noise barrier priorization program whereby existing residential locations with reversed frontage, adequate open space and experiencing noise levels of 70 dBA Leq (24) or above be considered for noise barrier attenuation subject to ranking according to the proposed Noise Monitoring Program and the availability of funds.	It has been determined from the State of the Art Review of North American Abatement Policies and Programs that a majority of government agencies recognize that the capital costs associated with noise attenuation by means of an acoustical barrier are not considered cost effective unless a 10 dBA or greater noise level reduction is required to achieve an acceptable noise level. A barrier Priorization Program is required to mitigate only excessive traffic noise problem locations of 70 dBA Leq or greater.	The Transportation Management Department identify candidate attenuation sites that are not already included in Functional Roadway Plans and to submit the list of sites to the Engineering Department for inclusion in the 5 Year Roadway and Transit Construction Program.
4.5.1.2			That City Council direct the Engineering Department to establish a separate Special Capital Project within the 5 and 10 year Roadway and Transit Improvement Program, setting out funding for identified noise attenuation projects, and annually, as part of the Capital Budget deliberations, establish a barrier priorization program in conjunction with the priorities of the total capital budget program, according to a priority index or as required, until the needs are met.	The Engineering Department has an appropriate capital budget that could fund capital work projects of this nature for the City.	The Engineering Department establish the appropriate capital budget.

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4.5.2			Citizen Information Program		
4.5.2.1			That the Transportation Management Department establish a Citizen Information Program for the purpose of explaining the municipal traffic noise policies, programs and also abatement measures that may be employed by individual homeowners to improve their indoor sound environment.	A citizen information program provides the mechanism for: - explaining the principles of traffic noise propagation. - to advise homeowners of appropriate noise attenuation measures they may implement to reduce indoor noise levels and possible grant funding assistance. - to explain municipal noise standards and policies.	The Transportation Management establish a Citizen Information Program as recommended.
4.6			OTHER MEASURES FOR APPLICATION BY THE MUNICIPALITY		
4.6.1			Purchase of City Vehicles		
4.6.1.1			That City Council direct the Central Supply and Services and Transit Departments to address within the specifications, developed for the purchase of City vehicles, the noise levels and limits of the equipment, and specific noise level limits in dBA, taking into consideration the type of vehicle and current technology.	The implementation of the program would indicate the City's sincerity and seriousness in dealing with noise problems and would also serve as an encouragement to manufacturers to reduce vehicle noise emissions. The specifications should address the noise levels thereby giving all potential bidders the same opportunity to comply, with the objective of giving preference to any manufacturer which might have vehicles operating at a lower dBA rating.	The Central Supply and Services and Transit Depts. to undertake the necessary action to comply with the stated recommendations.

REFERENCE NUMBER Vol.I	Vol. II	Vol.III	RECOMMENDATION	RATIONALE	ACTION REQUIRED
4.6.2			Acoustical Barrier Standards		
4.6.2.1			That City Council direct the Engineering Department to prepare a Barrier Design Standards Manual for the purpose of ensuring that barrier noise attenuation facilities are effective, easily maintained, durable and aesthetically acceptable, and in the interim to continue to use the existing list of design guidelines as presented in Appendix V.	The municipality is usually responsible for maintaining barriers constructed by the Development Industry within road right-of-ways and therefore it is important to ensure the construction of effective, easily maintained, durable and aesthetically acceptable acoustic barriers.	The Engineering Dept. with assistance from the Transportation Management Dept. to prepare a comprehensive barrier design standards manual as recommended.
4.6.3			Municipal Control of Land		
4.6.3.1			That City Council direct the Transportation Management Department to attenuate residential noise problems through the municipal control of land, where residential property adjacent to arterial roadways is experiencing noise levels in excess of 70 dBA Leq (24) in the outdoor amenity area and cannot be attenuated by a standard noise barrier due to technical constraints, pending the availability of funding assistance from the Province.	The municipal control of land is necessary for resolving noise problems, particularly for excessive noise level situations where the use of physical barriers is not technically or economically possible. At this noise level residential habitation is unacceptable and and immediate action to mitigate noise problems is necessary. For these circumstances, the affected land use should be purchased by the City to provide a land setback buffer, space for the installation of a berm and/or wall, or for municipal redevelopment with compatible land uses or sold to the private sector with appropriate convenants on the deed to ensure that only compatible land uses are developed, upon concurrance with a majority of the affected property owners.	The Transportation Management Department implement the stated recommendation where feasible.

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4.6.3.2	That City Council direct the Planning Department to consider redistricting residential property, adjacent to arterial roadways, that is experiencing traffic noise levels greater than 65 dBA Leq (24) in the outdoor amenity area, to a more compatible land use in conjunction with existing and proposed Area Redevelopment Plans, upon concurrance with a majority of the affected property owners.	The redistricting of residential property is an effective method of allowing the eventual redevelopment of noise incompatible land uses, particularly where noise attenuation facilities are economically or technically impractical. Existing Area Redevelopment Plans contain many residential noise problem locations within their boundaries.	The Planning Department to implement the stated recommendations where appropriate.
4.6.4	Future Noise Studies		
4.6.4.1	That City Council direct the Transportation Management Dept. to undertake a study regarding land use policies and associated noise standard for residential land uses adjacent to railway corridors.	At this time, no existing land use or noise policies have been adopted by the City to deal with residential noise problems adjacent to existing rail Corridors.	The Transportation Management Dept. to carry out a study of rail noise for the purpose of developing acceptable policies and standards for inclusion in the Municipal Land Use Bylaw.

APPENDIX II

IMPLEMENTATION RESPONSIBILITIES FOR RECOMMENDATIONS

This appendix outlines the implementation responsibilities of various parties for initiating action and for following through with the implementation of the study recommendations. The parties indicated to undertake major responsibilities are denoted in upper case lettering while the parties with input responsibilities only are denoted in lower case lettering.

RECOMMENDATION	MAJOR RESPONSIBILITY FOR INITIATING ACTION	MAJOR RESPONSIBILITY FOR IMPLEMENTATION
	*Input Responsibility	*Input Responsibility
1. REVISED RESIDENTIAL NOISE LEVEL STANDARD	TMD * Planning * All Study Participants	PLANNING * Transportation Management
2. AMENDMENTS TO EXISTING SENIOR GOVERNMENT LEGISLATION		
a) Vehicle Noise Emissions	TMD * Alberta Transportation * Transport Canada * Executive Services	TRANSPORT CANADA
b) Tire Standards and Pavement Design	TMD * Transport Canada * Executive Services	TRANSPORT CANADA
c) Building Code Regulations	TMD * Alberta Department of Labour * Executive Services * National Research Council	ALBERTA DEPT. OF LABOUR NATIONAL RESEARCH COUNCIL * Central Mortgage and Housing
d) Health Regulations	TMD * Provincial Board of Health * Executive Services	PROVINCIAL BOARD OF HEALTH

RECOMMENDATION	MAJOR RESPONSIBILITY FOR INITIATING ACTION		MAJOR RESPONSIBILITY FOR IMPLEMENTATION	
	*Input Responsibility		*Input Responsibility	
e) Planning Act Legislation	TMD CITY OF CALGARY	* Planning * Executive Serv. * Alberta Municipal Affairs	ALBERTA MUNICIPAL AFFAIRS * Transportation Management * Planning * City of Calgary Transportation Dept.	
f) Provincial Cost Sharing of Noise Attenuation Measures	TMD	* Alberta Transportation	ALBERTA TRANSPORTATION	
g) Funding Assistance for Retrofit Program	TMD	* CMHC	CMHC	* Planning (R.R.A.P. Officers)
h) Formation of Quiet Communities Directorate	ENVIRON. COUNCIL	* Alberta Municipalities * Municipal Affairs	MUNICIPAL AFFAIRS	* Alberta Municipalities
3. AMENDMENTS TO EXISTING MUNICIPAL LEGISLATION				
a) General Municipal Plan	TMD	* Planning * Public	PLANNING	* Transportation Management
b) Land Use Bylaw	TMD	* Planning * Public	PLANNING	* Transportation Management
c) Terms of References ARP, ASP and NSP	TMD	* Planning	PLANNING	* Transporation Management

RECOMMENDATION	MAJOR RESPONSIBILITY FOR INITIATING ACTION	MAJOR RESPONSIBILITY FOR IMPLEMENTATION
	*Input Responsibility	*Input Responsibility
d) Municipal Noise Abatement Bylaw	TMD * Law, Planning * Bylaw Enforcement * Police, Parks and Recreation * Real Estate & Housing * Alberta Trucking Association * Health * Public	BYLAW ENFORCEMENT POLICE * Health Department
e) Property Assessment	TMD * Assessment * Engineering	ASSESSMENT * Transportation Management * Engineering
4. MUNICIPAL NOISE ABATEMENT AND INFORMATION PROGRAMS		
a) Barrier Priorization Program	TMD * ENGINEERING	ENGINEERING * Transportation Management
b) Citizen Information Program	TMD * CMHC	TMD * Public Relations * CMHC
5. OTHER ABATEMENT MEASURES FOR APPLICATION BY THE MUNICIPALITY		
a) Purchase of City Vehicles	TMD * Transit * Central Supply And Services	TRANSIT CENTRAL SUPPLY AND SERVICES

RECOMMENDATION	MAJOR RESPONSIBILITY FOR INITIATING ACTION		MAJOR RESPONSIBILITY FOR IMPLEMENTATION	
	*Input Responsibility		*Input Responsibility	
b) Acoustical Barrier Standards	TMD	* Engineering	ENGINEERING	* Transportation Management
c) Municipal Control of Land	TMD	* Planning	PLANNING TMD	* Public

APPENDIX III

SUMMARY OF THE EFFECTS OF NOISE

This appendix describes some aspects of the effect of noise on people in residential areas to varying levels of cumulative exposure. This information was derived from the literature review undertaken during the course of the study.

SUMMARY OF THE EFFECTS OF NOISE ON PEOPLE
(Residential Land Uses Only)

EFFECTS	HEARINGS LOSS	SPEECH INTERFERENCE		SLEEP INTERFERENCE	ANNOYANCE	AVERAGE COMMUNITY REACTION
		Indoor	Outdoor			
SOUND LEVEL IN DECIBELS	Qualitative Description	%Sentence Intelligibility	Distance in Metres For 95% Sentence Intelligibility	Qualitative Description	%of Population Highly Annoyed	
75 and Above	May Begin To Occur	98%	0.5	Will Occur	37%	Very Severe
70	Will Not Likely Occur	99%	0.9	Will Occur	25%	Severe
65	Will Not Occur	100%	1.5	Will Begin to Occur	15%	Significant
60	Will Not Occur	100%	2.0	Will Not Likely Occur	9%	Moderate To
55 and Below	Will Not Occur	100%	3.5	Will Not Occur	4%	Slight

GENERAL COMMUNITY ATTITUDE TOWARDS LOCAL AREA	ESTIMATED POPULATION IN EDMONTON EXPOSED ARTERIAL ROADWAY NOISE (1980)	ADMINISTRATION COST IMPLICATIONS	RESIDENT COST IMPLICATIONS	DEVELOPMENT INDUSTRY COST IMPLICATIONS
Noise is likely to be the most important of all adverse aspects of the local environment.	0	$0	No Costs	No Cost
Noise is one of the most important adverse aspects of the local environment.	51,000	$0	No Direct Costs	No Cost
Noise is one of the important adverse aspects of the local environment	44,000	$5,535,000	Direct Costs	Limited Cost
Noise may be considered an adverse aspect of the local environment	16,500	$24,705,000	No Direct Costs	Moderated Cost
Noise is considered no more important than various other environmental factors.	18,500	$28,845,000	No direct Costs	Very Costly

APPENDIX IV

DATA REQUIREMENTS AND PROCEDURES FOR NOISE LEVEL MEASUREMENT AND CALCULATION

The purpose of this appendix is to outline the data requirements and procedures to be used for the measurement and calculation of traffic noise levels. The data requirements and procedures have been derived from practical experience both in Edmonton and elsewhere.

1. Noise levels must be measured using the A-weighted 24 hour equivalent sound level Leq(24) expressed in decibels (dBA) and be based on the higher of the Average Annual Daily Traffic Volume or Summer Average Daily Traffic Volume for existing residential areas.

2. In the case of new residential development or in the evaluation of barriers the ultimate design capacity must be used for the projection of traffic volumes in noise studies unless it can be established that the ultimate design capacity will not be reached.

3. Noise levels should be calculated using traffic noise prediction methods that are endorsed by the Transportation Management Department. These methods are: the Alberta Surface Transportation Noise Attenuation Study Manual for the Prediction of Surface Transportation Noise; the Canada Mortgage and Housing Corporation method; the Federal Highway Administration method-Stamina 2.0/Optima; or some other technically accurate and acceptable method of noise prediction.

4. Traffic volumes shall be 1/24 of the daily volume.

5. Vehicle speed shall be the posted speed.

6. Truck volumes shall comprise 15% of the total traffic flow, unless known by actual traffic count.

7. Noise monitoring receptors shall be located in the outdoor amenity area, 1.5 metres above typical ground elevation and approximately 3 meters away from the dwelling wall. This observer distance also applies to noise level calculations.

8. For design purposes, traffic volumes shall be based on level of service C, ie. the noisiest condition.

9. For the purpose of measuring the interior noise level, the noise monitoring receptors shall be located approximately 3 meters from the front of the dwelling. A 3 dBA correction factor should be subtracted from this measured noise level to account for sound energy reflecting from the building. This noise level may be used as a representative indicator of the interior noise level by subtracting from this noise level, the generally accepted standard noise level reduction of 15 dBA (or greater depending on the use of acoustical building materials), that may be attributed to standard building face construction. This procedure should result in acceptable noise levels within the dwelling unit.

APPENDIX V

INTERIM ACOUSTICAL BARRIER DESIGN GUIDELINES

The purpose of this appendix is to provide interim guidelines for the design and construction of acoustical barriers that are to be followed by both the Civic Administration as well as the private development community. These guidelines were derived from those currently in use by the City. These guidelines will be eventually replaced with more detailed specifications that will be prepared by the Engineering Department and will be included in the City Servicing Standards Manual.

ACOUSTICAL BARRIER DESIGN GUIDELINES

The following acoustical barrier standards are interim guidelines specifying requirements for the construction of such facilities:

1. The noise barrier must be acoustically designed so as to reduce noise levels to the objective noise level of 60 dBA Leq(24).

2. Noise attenuation facility minimum height required is 3.5 meters above general site grade. All property required for noise attenuation is in addition to road right-of-way. Design of any noise attenuation facility is a responsibility of the developer and must be to the satisfaction of the Engineering Department.

3. If a berm of a height of 2 meters or more is to be used, a 3 meter berm top is required. Noise attenuation walls or screen fences should be centered on the berm. The location of the wall or fence will define the property line. The 1.5 meters on the public side of the fence or wall should include .65 meter rounding from the slope to the top.

4. Minimum 3:1 side slopes on public side of berm; 95% compaction of berm material.

5. Noise walls which are to be in part publicly maintained must be constructed of steel sheeting or concrete compound. Minimum density required is 8.5 Kg/m^2 (1.75 lb/ft^2) for steel, 17 Kg/m^2 (3.5 lb/ft^2) for other materials (Source: Alberta Surface Transportation Noise and Attenuation Study).

6. Minimum 1/30 years wind pressure loading 110 Kg/m^2 (22.5 lb/ft^2) to be used.

7. The facility should be continuous with no holes, cracks or gaps and should extend into the ground to a depth of 6 inches.

8. Trees, plants or other forms of vegetation must not be planted on the top of the berm, and should be limited to the lower portion of the berm slope.

9. Landscaping for the purpose of improving the aesthetic characteristics of an acoustic barrier must meet the standards of the Parks and Recreation Department.

10. An acoustic barrier must extend a distance beyond the last receptor of excessive noise, equal to 4 times the perpendicular distance from the receptor to the barrier, or the barrier must be designed to wrap around the last receptor, so that the last receptor receives the required acoustical protection.

11. The visual continuity of acoustic barriers must be maintained if an existing facility is nearby, through the use of the same construction materials, techniques and design considerations.

12. Any proposed variance to these requirements must be accompanied by a letter from a certified acoustical engineer stating that the barrier proposed will attenuate noise to a level of 60 dBA Leq in the outdoor amenity area of the subject properties.

APPENDIX VI
GLOSSARY OF TERMS

The purpose of this glossary is to provide an aid in understanding acoustical terminology to all persons reading this report and those involved in noise and land use planning, and decision making, including planners, elected officials, the private development community and the general public.

GLOSSARY OF TERMS

A-Weighted Sound Level: The sound level as measured on a sound level meter, using a setting that emphasizes the middle frequency components similar to response of the human ear. The a-weighted sound level is found to correlate well with subjective assessments of the annoying or disturbing effects of sounds.

Absorption: Absorption is a property of materials that reduces the amount of sound energy reflected. Thus, the introduction of an "absorbent" into the surfaces of a room will reduce the sound pressure level in that room by virtue of the fact that sound energy striking the room surfaces will not be totally reflected. It should be mentioned that this is an entirely different process from that of transmission loss through a material, which determines how much sound gets into the room via the walls, ceiling, and floor. The effect of absorption merely reduces the resultant sound level in the room produced by energy which has already entered the room.

Ambient Noise Level:	The sound level of background noise characteristic of an environment. Practically speaking, the level of a specific sound must be above the ambient noise level in order to be perceived.
Annoyance:	General term encompassing adverse citizen opinion of a roadway that generally correlates with noise level increases caused by peak hour traffic or trucks. Annoyance is generally predicted by the amount the vehicular noise that exceeds the existing neighbourhood noise.
Attenuation:	A reduction in sound level in travelling from a source to a receiving point.
Barrier:	A solid physical obstruction between the roadway and the observer, which interrupts the line of sight between them.
Barrier Attenuation:	The reduction in level of sound travelling over hard ground resulting from a barrier between source and receiving point.
Berm:	A mound of earth that interrupts the line of sight between a source and receiving point, thus acting as a barrier.

Day Night Average Sound Level: (Ldn)	Day-night sound level in dBA is derived by averaging time varying sound energy over the daytime (daytime Leq) with the varying sound energy over the nighttime (nighttime Leq) to which an additional ten decibel weighting is applied to the nighttime hours between 2200 to 0700.
Decibel (dB):	One tenth of a bel. Sound is measured in decibels. The zero on the decibel scale is based on the lowest sound level that the healthy, unimpaired human ear can detect. Decibels are not linear units, but representative points on a sharply rising (exponential) curve. Thus, 100 decibels represent 10 billion times as much acoustic energy as one decibel.
Equivalent Level (Leq):	An hourly unit of noise. The Leq condenses an hour's worth of noise fluctuations into a single number, with units of dBA. The Leq is also called the "energy-equivalent level". Leq(24) is the average noise level over a 24 hour period.
Line Source of Noise:	A source of noise spread out into a line, such as the combined traffic on a roadway or railway.
Loudness:	A psychological quantity that corresponds to noise intensity where a ten-fold increase in noise energy results in a two-fold increase in loudness. Similarly, a ten-fold decrease in noise energy is heard as a halving of the loudness.

Noise Sensitive Land Uses:	Noise sensitive land uses include: residential, schools, libraries, churches, hospitals, auditoriums and outdoor recreation areas. These typify land uses whose suitability is restricted by intrusive noise, hence are termed "noise sensitive". Noise sensitivity factors include: interference with speech communication; subjective judgements of noise acceptability and relative noisiness; need for freedom from noise intrusion; and sleep interference criteria.
Point Source of Noise:	A source of noise essentially concentrated at a single source, such as noise from a single vehicle.
Propagation:	The passage of sound energy from noise source to observer.
Sound Insulation:	The use of structures and materials designed to reduce the transmission of sound from one room or area to another or from the exterior to the interior of a building.

APPENDIX VII

REFERENCE DOCUMENTS

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